THE EFFECTS OF SHIP LOAD VARIATIONS AND SEASTATE ON HULL GIRDER DEFLECTION AND COMBAT SYSTEM ALIGNMENT

by

STUART HAYDEN MENNITT

B.S. Naval Architecture and Marine Engineering
Webb Institute of Naval Architecture (1986)

Submitted to the Department of
OCEAN ENGINEERING
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
September, 1990

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ABSTRACT

This thesis computationally analyzes the effect of commonly occurring ship load variations and wave induced bending moments on hull girder flexure. The deflection of the hull is used to determine the impact on the alignment of the vessel's combat system. Simple beam theory is applied for the structural portion of the analysis. Wave induced bending moments are determined by using a quasi-static approach with regular waves. Calculations and results are presented for the FFG7 class of U.S. Navy frigates.

It is shown that commonly occurring load conditions produced no significant problems with the alignment of the ship's combat system. The effect of waves can be more significant. Deflections of up to 9 arc minutes are predicted between elements of the combat system in seastate 6. This is out of the elements' alignment tolerance and could affect the operability of the system.

Thesis Supervisor: Professor Richard Celotto
Title: Associate Professor of Naval Construction and Engineering

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Sincerely,

Stuart Mennitt

CONTENTS

List of Figures

List of Tables

1. Introduction

A warship's effectiveness in combat depends predominantly on the effectiveness of its combat system. The effectiveness of a weapon system depends on proper interaction of its constituent subsystems. Modern naval combat systems are comprised of many complex subsystems. These subsystems are integrated in a way that attempts to maximize the overall performance of the vessel.

Various integrated systems and subsystems comprise a modern warship's combat system. This integration requires a correct exchange of information between the different systems and subsystems in order that the combat system function properly as a whole. The successful exchange of information requires both the actual passing of accurate electronic data and the use of a common physical frame of spatial reference. The latter is made possible by the physical alignment of combat system components relative to a common reference system.

Initial combat system alignment is accomplished at the shipyard as part of new construction. Once the vessel is in the fleet, the US Navy requires that the combat system be aligned periodically. A complete combat system alignment can take over a week and requires a certain ship loading condition as well as nearly constant sea and air temperature. It is only practical for a warship to undergo a complete combat system alignment when it is in a shipyard for construction, conversion, repair, or overhaul.

Complete combat system alignments are typically done during selected restricted availabilities which occur every eighteen to twenty-four months. Selected restricted availabilities are limited overhauls that usually last less than six months. The initial alignment, performed at the builder's shipyard, is required to be carried out while the ship is floating at a displacement of at least 90% for Builder's Sea Trials.[1] Thereafter, alignment procedures are required to be performed when the ship is at a condition of at least 80% of its total load.[2] Thus, effects such as transition from drydock to afloat, changed configuration, and settling of ship structure are minimized. While the 90% Builder's Sea Trial displacement and "total load" specifications are vague, they attempt to bring the ship close to a full load condition for alignment.

During the period of time between these alignments, there are many factors that contribute to alignment degradation. Combat system alignment errors can be categorized as being either static or dynamic in nature. Tables 1-1 and 1-2[3] summarize these errors and the causes behind them.

The static misalignment errors in Table 1-1 are the result of improper alignment procedures and are not inherent in the ship's design. Some of the errors mentioned in Table 1-2 are the result of poor design or integration of a weapon or component. The result of the latter is that the element cannot dynamically compensate for the vessel's motion in a seaway.

Of the remainder of the causes of errors in combat system alignment, three are common to all surface combatants:

- Structural distortion due to thermal effects

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[1]General Specifications for Ships of the United States Navy, S9AA0-AA-SPN-010/GEN-SPEC, Naval Sea Systems Command, 1989, Section 184.

[2]Combat System Alignment Manual (CSAM) for FFG7 Class, SW225-B6-CSA-010/OP2456 FFG7 CL, 2nd Revision, Naval Sea Systems Command, 15 August 1987, p. 1-8.

[3]Technical Manual for Theory of Combat System Alignment, SW225-AO-MMA-010/OP762ALIGNTHEORY, 2nd Revision, Naval Sea Systems Command, 1 September 1987, Section 1-2.20.

- Structural distortion due to wave induced stresses
- Structural distortion due to loads depletion

Table 1-1: Static Alignment Error Sources

Error	Source
1. Step-type errors	a. Transition from drydock to afloat b. Structural distortion due to heavy seas, storms, etc. c. Structural distortion due to configuration change (e.g., modernization of sonar equipment) d. Fuel and ammunition loadout.
2. Static misalignment	a. Roller path inclinations of system equipment b. Dial and synchro zero adjustment c. Improper alignment from offset centerline, tram settings, benchmarks, etc.
3. Slowly varying errors	a. Fuel and ammunition depletion b. Settling of ship structure (new ship, overhaul, etc.) c. Solar/thermal expansion

Table 1-2: Dynamic Alignment Error Sources

Error	Source
1. Hull distortion	a. Wave induced bending b. Ship maneuvering
2. Other	a. Uncompensated roller path changes due to gun movement b. Inability of stable element to reflect ship motion c. Inability of weapon system to respond to ship movement d. Ship internal equipment movement and vibration

The three modes of hull structural distortion are shown in Figure 1-1. Thermal effects and wave stresses can produce all three components. Load variations can induce hull flexure in only the vertical bending and torsional modes. The stresses that a seaway puts in a ship's hull are generally most severe in the vertical bending mode. For this reason, the primary stresses resulting from a wave induced bending moment are considered the main design criteria for the hull structural strength of most vessels.[4]

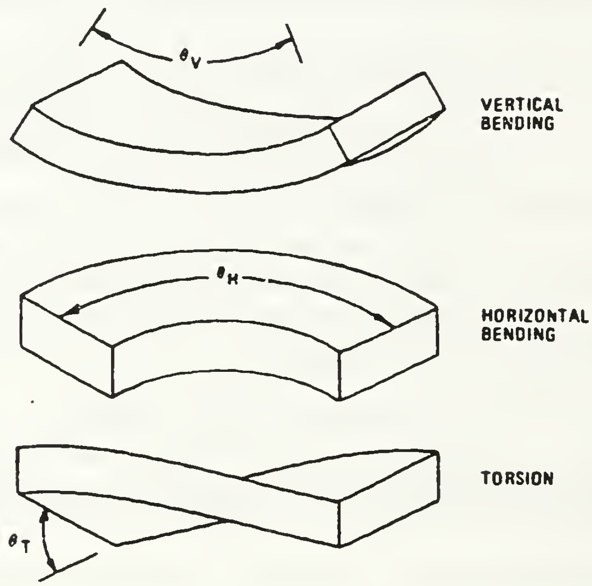

Figure 1-1: Modes of Hull Flexure

Hull flexure caused by changes in loading is also primarily in the vertical bending mode. It is possible in most vessels to obtain some torsional flexure by diagonally distributing loads. This would, however, be a very uncommon occurrence for a warship. Load items tend to be consumed evenly when distributed port and starboard.

Like hull flexure caused by wave action and variations in loading, flexure due to thermal differentials in the hull structure is most often in vertical bending. The flexure is due to a temperature differential between regions of the hull structure. This is most

[4]Principles of Naval Architecture, 2nd Revision, The Society of Naval Architects and Marine Engineers, Jersey City, NJ, 1988, Vol. 1, Section 3.

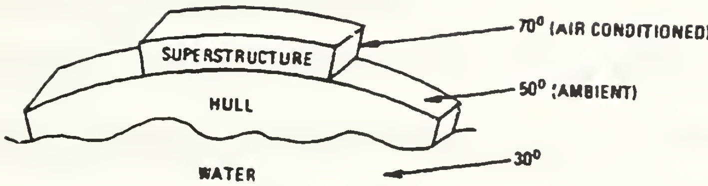

Figure 1-2: Thermal Flexure

common between the underwater portion of the hull and the above water portion. Figure 1-2 depicts a vessel that is undergoing flexure in vertical bending due to the temperature difference between the sea and the air. Uneven solar heating (port or starboard) would tend to flex the hull horizontally. Only a complex and unlikely combination of hull heating and cooling would result in a torsional flexure.

These three causes are of potential concern to the warship operator. For example, assume the vessel's combat system is aligned with the ship near full load condition, in calm water, and in weather conditions that minimize temperature differences within the hull. The vessel then puts to sea. Fuel is used up, and ballast water is added. The ship encounters waves. The sun warms the hull above the waterline. The structure of the ship distorts as a result of these causes. The operator may assume his ship's combat system is still in alignment. It is possible that, without the operator's knowledge, one or more of these causes has distorted the shape of the vessel to the point of creating significant misalignment between elements of the combat system. If the ship returns to port and the alignment is checked under conditions of hull temperature, load, and seastate similar to when the system was initially aligned, everything would be within specifications. The problem with misalignment in the operational environment would remain undetected.

This thesis presents a study of the effects of ship load variation and seastate on hull girder deflection and combat system alignment. A goal is to assess the possibility that US Navy ships may be operating at sea with combat systems not in alignment. The author acknowledges the significance of hull deflections due to temperature variations. Thermal effects on a ship's structure are relatively complex and require detailed finite element analysis for meaningful results. Such an undertaking is beyond the scope of this project. The effects of load variations and seastate on hull girder deflection are, however, within the scope of this study.

The study focuses on the FFG7 class of US Navy frigates. Due to the nature of the calculations, it is not realistic to work with a generic ship. Although one can conjecture on a theoretical basis as to the qualitative effects of shipboard load changes and seastate on combat system alignment, to determine the magnitude of the effects and ascertain whether or not any cause for concern exists requires studying a defined vessel. Specific information is required concerning hullform, scantlings, and lightship and loads weight distribution. It is expected that this study will be of interest to the operators of these vessels as well as to US Navy ship designers and combat system engineers.

Calculations are made at four load conditions: full load, 80% fuel load, 60% fuel load, and minimum operating condition. The still water condition is used to establish baseline deflection and alignment. Wave effects are analyzed at the full load condition using the quasi-static method. Regular trochoidal wave profiles of varying heights are used to represent seastates 2, 4, and 6.

2. Description of the FFG7 Class Frigate

The FFG7 class is the most modern frigate in the US Fleet. The first ship of the class was commissioned in December of 1977. A total of fifty-four have been built, with the final ship in the class, the FFG61, being commissioned in July of 1989.

Table 2-1[5],[6] contains some characteristics of the FFG7 class. FFG8 and later ships of the class, FFG36-61, are modified to incorporate the Light Airborne Multi-Purpose System Mk III (LAMPS III). The major components of this upgrade are the SH-60B helicopter and the Recovery Assist Secure and Traverse (RAST) system. The transom of these modified ships are angled aft to provide more space for the RAST equipment and the larger helicopters. The total displacement is higher due to both a higher lightship weight and additional loads. The hull scantlings on the LAMPS III frigates are increased slightly to provide the additional hull strength needed due to the higher displacement.[7]

The FFG7's primary mission is anti-submarine warfare (ASW). It also has secondary capabilities in anti-air (AAW) and anti-surface warfare (ASU). The combat system of the FFG7 class is described in Table 2-2[8],[9]. Also included in Table 2-2 are navigational and radio elements that are sensitive to alignment. Figure 2-1 contains

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[5]Jane's Fighting Ships 1988-89, Jane's Publishing Company Limited, London, 1988, p. 762.

[6]FFG61 Final Weight Estimate, July 1989, Gibbs & Cox, Inc.

[7]FFG36-61 Longitudinal Strength and Inertia Sections Drawing, NAVSHIPS Drawing No. PF109-802-5414870.

[8]Jane's Fighting Ships 1988-89, pp. 762-3.

[9]Norman Polmar, The Ships and Aircraft of the U.S. Fleet, 12th Edition, Naval Institute Press, Annapolis, 1981, pp.115-6.

Table 2-1: FFG7 Class Dimensions

Item	FFG7, 9-35	FFG8, 36-61
ASW	LAMPS I	LAMPS III
Helicopters	2 x SH-2F	2 x SH-60B
RAST	No	Yes
LBP	408'-0"	408'-0"
LOA	445'-0"	453'-0"
B-max	46'-11.5"	46'-11.5"
D-amidship	30'-0"	30'-0"
Disp.:		
Lightship	2750 ltons	3096 ltons
Full Load	3585 ltons	3987 ltons
Machinery:		
Main Engines	2 LM2500 gas turbines, 41000 shp total	2 LM2500 gas turbines, 41000 shp total
Auxiliary	2 x 325hp auxiliary propulsion units	2 x 325hp auxiliary propulsion units
Generators	4 x 1000 Kw diesel generators	4 x 1000 Kw diesel generators
Speed, Sustained	29 knots	29 knots
Range	4500 nm @ 20 knots	4500 nm @ 20 knots

an outboard profile of the FFG7 class and shows the location of many of the items in Table 2-2. Figure 2-1 also specifies alignment tolerances which are described in Chapter 3.

Table 2-2: FFG7 Class Combat System

Primary Combat System Components	
Missiles: Mk 13 Launcher	 Single arm launcher, 40 round rotary magazine, launches SM1-MR (medium range) AAW and Harpoon ASU missiles.
Guns: Mk 75 76mm Mk 15 CIWS	 Dual-purpose rapid fire 76mm gun capable of engaging both air and surface targets. Close in weapons system, point anti-missile defense, 20mm radar controlled gun.
Torpedoes: 2 Mk 32 Launchers	 Two triple tube mounts firing Mk 46 lightweight ASW torpedoes.
Countermeasures: 4 Mk 36 SRBOC SLQ 32V(2) SLQ-25 NIXIE	 Super rapid-blooming offboard chaff. Launches chaff canisters and infra-red decoys. ESM/ECM, threat radar warning receiver. Torpedo decoy/countermeasure system.
Fire Control: Mk 92 Mod 2 FCS 2 Mk 24 TDT	 Integrated missile and gun fire control. Target designation transmitter, optical manual sight for Mk 75 gun.
Radars: SPS 49 SPS 55 SPG 60 STIR Mk 92 CAS	 Long range two-dimensional (range and bearing) air search radar. Surface search/navigation radar. Separate target illumination radar, director for SM1-MR and Mk 75 gun in AAW mode. Combined antenna system, search and track for Mk 92 FCS and director for Mk 75 gun in ASU mode.
Sonars: SQS 56 SQR 19 TACTAS	 Active/passive hull mounted sonar. Passive towed array sonar.
Helicopters: 2 SH-2F or 2 SH-60B	 LAMPS I LAMPS III
Other Alignment Sensitive Equipment	
URN-25 TACAN URD-4	Tactical air navigation system. Radio direction finding device.
WSN-2 Mk 27 GC Pelorus Stand SGSI	Gyrocompass, primary. Gyrocompass, backup. Optical orientation determination apparatus. Stabilized glide slope indicator, for helicopter landing approach.

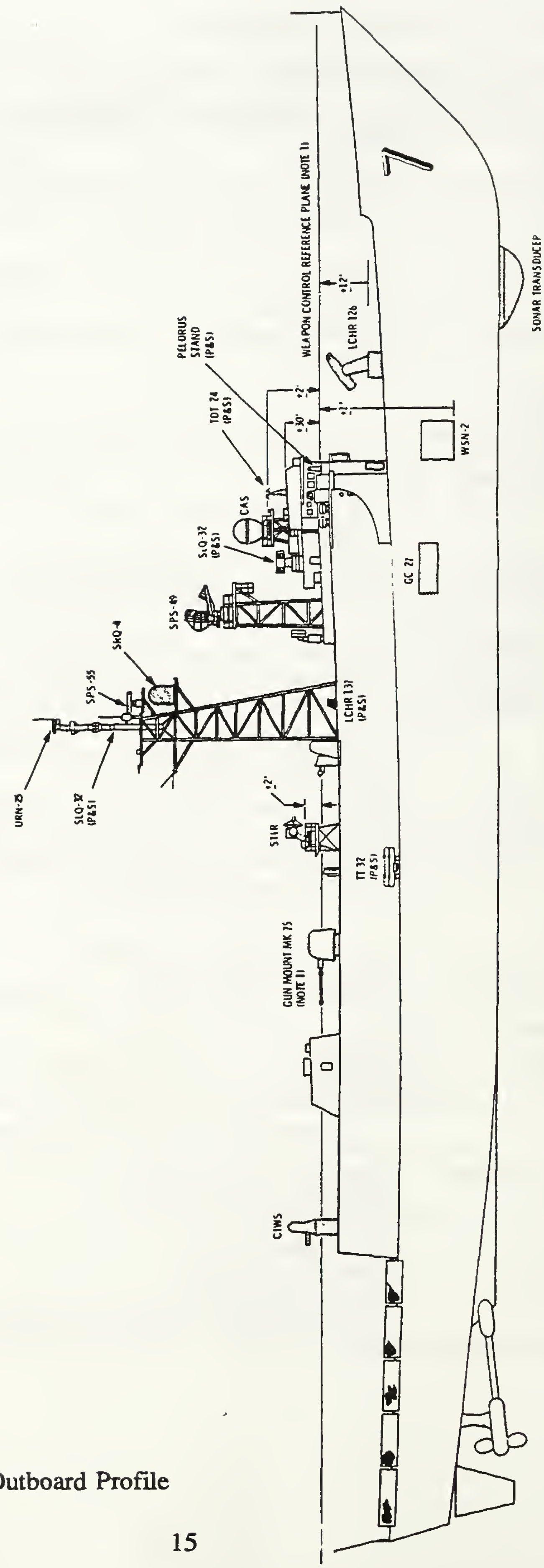

Figure 2-1: FFG7 Class Outboard Profile

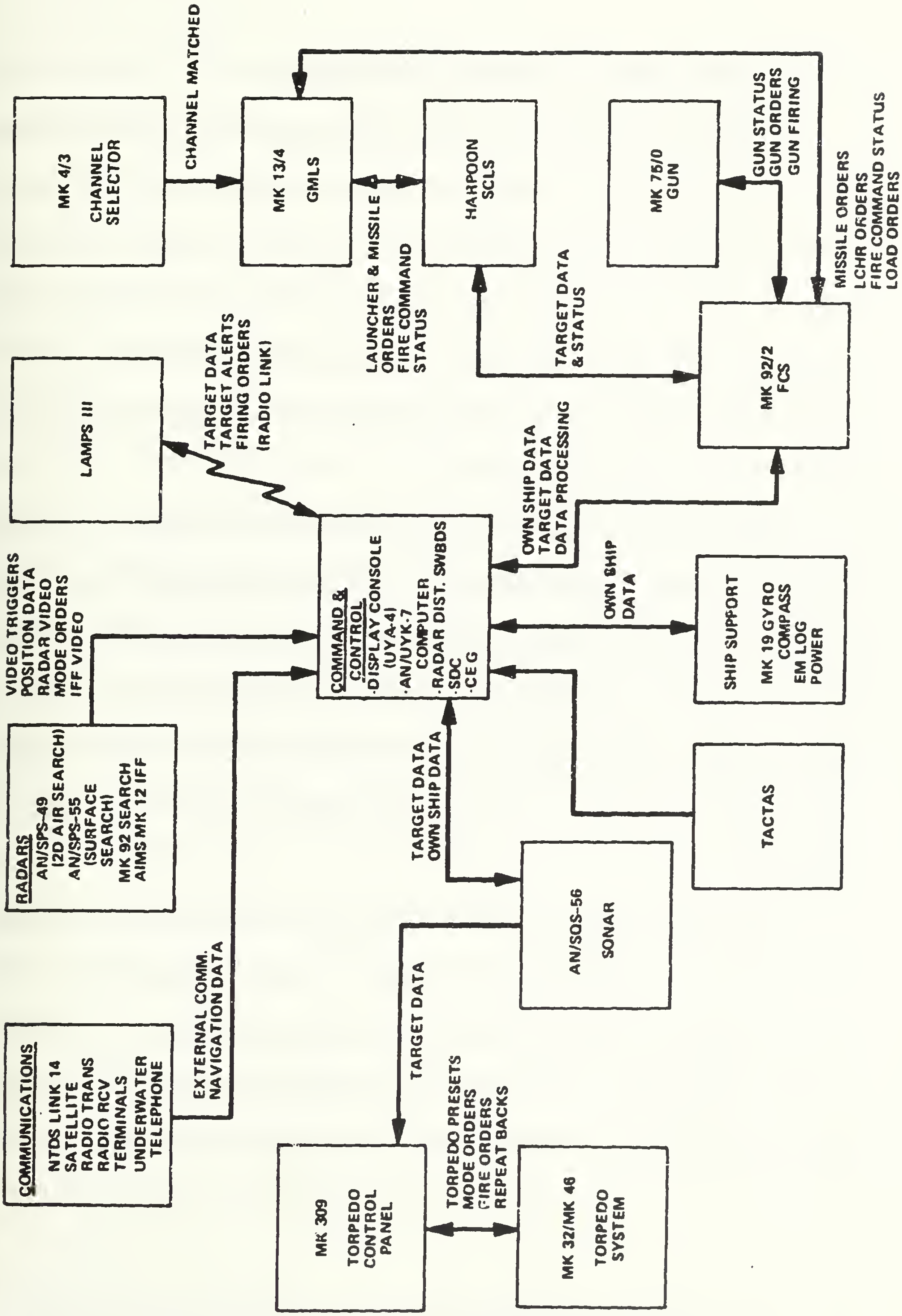

Figure 2-2: FFG7 Class Combat System Block Diagram

3. Alignment Requirements and Tolerance

To achieve the performance of which a combat system is capable, each subsystem must by physically aligned to required tolerances. Alignment tolerances are based on individual equipment criteria and represent the minimum acceptable standards of alignment. At the same time the alignment tolerances must be realistic, considering both that which is achievable in an industrial environment as well as maintainable in an operational environment. Only when this alignment is maintained can the combat system be expected to satisfy tactical requirements.

Each component that is sensitive to alignment must be aligned to a common reference to ensure a proper exchange of data between the various systems and subsystems. All missile launchers, gun bores, radar antennas, fire control directors, gyrocompasses, and other directional pointing equipment must be able to achieve a parallel condition with each other. These pointing lines must be able to remain parallel within acceptable tolerances. Combat system alignment refers to establishing this parallelism.

Combat system alignment is based on the concepts of parallel lines and planes and reference frames. The lines which are of interest are referred to as pointing lines. The pointing line may be a centerline of a torpedo tube, a propagation axis of a radar antenna, or a bore axis of a gun. The planes of interest are usually those in which the individual combat system components rotate. A reference frame is a combination of a fixed reference point, reference plane, and reference direction. A reference frame is used as a coordinate system to measure individual component planes and pointing lines.[10]

During new vessel construction the ship base plane (SBP) is the first reference plane to be established. The SBP is a horizonal plane that includes the ship's baseline. The centerline reference plane (CRP) is a vertical perpendicular to the SBP and includes the ship's centerline. The master reference plane (MRP) is a plane above the baseline that is parallel to the SBP. The MRP is defined early in the ship's construction by a master level block (MLB). The MLB is typically represented by a heavy machinery foundation or combination of foundations. In the FFG7 class the MLB is located in Auxiliary Machinery Room 1 (AMR 1). As the name implies, the MLB serves as a physical reference for further construction alignment. After construction, the MLB is only used in case of major damage or structural changes. The weapon control reference plane (WCRP) is then established. During new construction the WCRP is aligned parallel to the MLB (and thus to the MRP and SBP).

The WCRP serves as a reference plane for all combat system alignment requirements throughout the life of the ship. Equipment that rotates in a vertical axis does so about its roller path. For each of these components, the plane in space perpendicular to its vertical axis of rotation is called the roller path plane for that component. The roller path plane (RPP) of the Mk 75 76mm gun mount is the WCRP for the FFG7 class. Figure 2-1 shows the relative location of the Mk 75 gun relative to the other components of the FFG7 class combat system.

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[10]Technical Manual for Theory of Combat System Alignment, Section 2.1.

Reference marks are required in addition to reference planes. The main reference marks used are either on the ship's centerline or parallel to the centerline with a horizonal offset. Like the reference planes, the reference marks are established during new construction and are not altered under normal conditions.

The RPP's of all equipment in the combat syste: are aligned to the WCRP. This is usually done during initial construction by machining the roller paths and or their foundations. After machining, the parallelism between RPPs is checked. Any angle between two RPPs is referred to as the roller path inclination (RPI). The machining of each roller path must meet a specified RPI tolerance. Depending on the particular piece of equipment, it may be possible to later adjust the RPP with shims, leveling rings, or adjusting screws. If this second adjustment is possible, there will be a second set of RPI tolerances referred to as operational RPI tolerances. Both the foundation machining and operational RPI tolerances for the FFG7 class combat system are shown in Table 3-1[11].

The next alignment procedure is to perform train and elevation adjustments. The purpose is to ensure that all relevant elements of the combat system aim at the same point in space. Two methods are used for train and elevation alignment. One is train and elevation zero alignment. Each element of the combat system is brought to zero train (parallel to the CRP) and zero elevation (parallel to its RPP). This is accurately done using boresight telescopes and theodolites. A theodolite is an optical device similar to a surveyor's transit used to verify horizonal and vertical angles with precision. When zero train and elevation is reached, the controlling mechanism for each item being aligned is set to reflect the zero train and elevation condition.

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[11]Combat System Alignment Manual (CSAM) for FFG7 Class, p. 2-2.

Table 3-1: FFG7 Roller Path Inclination Tolerances

Equipment	Foundation machining		Operational roller path inclination		
	Tolerance	Reference	Tolerance	Reference	Remarks
Master Level Block	±0.5′	SCBP	N/A	N/A	
SPS-49 SPS-55	±10′ ±20′	MLB MLB	±20′ ±20′	WCRP WCRP	Achieved by shims
AS-3316/SLQ-32 CW-1186/SLQ-32 Mk 36 Launcher	±90′ ±30′ ±2°	MLB MLB MLB	N/A N/A N/A	N/A N/A N/A	
CIWS	±20′	MLB	N/A	N/A	
SQS-56 Transducer SVTT 32	±10′ ±30′	MLB MLB	±10 N/A	N/A	
CAS	±20′	MLB	±2′	WCRP	Achieved by adjusting screws
STIR	±5′	MLB	±2′	WCRP	Achieved by leveling rings
Mk 13 Launcher	±3′	MLB	±12′	WCRP	Achieved by machining
Mk 75 Gun (WCRP)	±3′	MLB	±3′	MLB	
TDT 24	±20′	MLB	±30′	WCRP	Achieved by shims
URN-25 URD-4	±60′ ±60′	MLB MLB	N/A N/A	N/A	
WSN-2	±20′	MLB	±1′	WCRP	Achieved by adjusting screws
Mk 27	±20′	MLB	N/A		
Pelorus Stand SGSI	±20′ ±60′	MLB MLB	N/A N/A	N/A N/A	

Table 3-2: FFG7 Train and Elevation Alignment Tolerances

Equipment	Construction tolerance		Operational tolerance[1]	
	Train[2]	Elevation[3]	Train	Elevation
Master Level Block	±0.5′	N/A	N/A	N/A
SPS-49	±30′[1]	N/A	±30′[4]	N/A
SPS-55	±30′	N/A	±30′[4]	N/A
AS-3316/SLQ-32	±30′[6]	N/A	N/A	N/A
CW-1186/SLQ-32	±30′	N/A	N/A	N/A
Mk 36 Launcher	±2°	N/A	N/A	N/A
CIWS	±20′	N/A	N/A	N/A
SQS-56 Transducer	±5′	N/A	N/A	N/A
SVTT 32	±60′	N/A	N/A	N/A
CAS	±1′	N/A	±2′	N/A
STIR	±1′	±1′	±2′[9,10]	±2′[9,10]
Mk 13 Launcher	±5′	±3′	±6′	±5′
Mk 75 Gun(WCRP)	±2′	±2′	±2′[9,10]	±2′[9,10]
TDT 24	±30′	±30′	±30′	±30′
URN-25	±60′	N/A	N/A	N/A
URD-4	±60′	N/A	N/A	N/A
WSN-2	±1′[7]	N/A	±12′[2,8]	±2′[5]
Mk 27	±2′[7]	N/A	±60′[8]	N/A
Pelorus Stand	±12′	N/A	30′	N/A
SGSI	±60′	N/A	N/A	N/A

NOTES:

1. Operational tolerances are achieved by various shipboard alignment procedures including horizon checks, star checks.
2. Referenced to the CRP.
3. Referenced to the RPP.
4. Referenced to the CAS.
5. Limit for roll and pitch is ±2′ operational, and ±1′for optical alignment.
6. This tolerance becomes ±12′ for ships equipped with the enhanced Band 1 antennas.
7. Construction train for these units represents the azimuth alignment tolerance to be met during optical alignment.
8. Operational train tolerance for these units include system alignment errors, heading accuracy, and alignment changes caused by ship's flexure due to mechanical, thermal, and dynamic loading (dockside only)
9. Tolerance for benchmarks is ±5′.
10. Tolerance for tram checks is ±3′.

The alternate method is a train and elevation space alignment. Boresight telescopes are used to bring the point lines of the combat system components to bear on a star. The range of the star ensures a negligible parallax error. Table 3-2[12] contains a summary of the FFG7 class train and elevation tolerances.

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[12] Combat System Alignment Manual (CSAM) for FFG7 Class, p. 2-3.

4. Hull Deflections Due to Changes in Loading

The calculation of hull deflection relies on the application of simple beam theory, which is commonly used in the analysis of ship hull girder primary stress and deflection. The hull is treated as a simply supported beam that has a distributed load applied. "Simply supported" implies that there are no concentrated moments applied to the hull girder. To be in static equilibrium the sum of the loads in any direction equals zero. This relates to the hydrostatic principle of a floating body's buoyancy being equal to its weight. The shear and moment is zero at the ends of the hull girder.[13],[14]

Many validations of the application of simple beam theory to ship hull bending behavior prediction have been documented.[15]

The following steps are taken in calculating hull deflections caused by both load variations and seastate:

1. Develop the longitudinal weight distribution of the ship in a baseline load condition.

2. Determine the still water longitudinal buoyancy distribution for the ship in the baseline condition.

3. Calculate the longitudinal shear distribution by integrating the load distribution (load=buoyancy-weight).

4. Calculate the longitudinal moment distribution by integrating the shear distribution.

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[13]Principles of Naval Architecture, p. 235.

[14]A. Higdon et al, Mechanics of Materials, 3rd Edition, John Wiley & Sons, Inc., New York, 1976.

[15]Principles of Naval Architecture, p. 235.

5. Calculate the hull deflection by performing a double integration of the moment and structural inertia distributions. The hull material modulus of elasticity must be included.

6. Repeat steps 1-5 using a new load condition or incorporating wave conditions in step 2.

The first step is to develop the longitudinal weight distribution of the ship in a baseline load condition. Due to minor changes during construction and outfitting, the weights vary slightly between ships in a class. It is appropriate to choose one ship for purposes of weight data. A detailed final weight report was available for FFG61. This weight report for the FFG61 is used throughout this study for all weight information.

The longitudinal strength drawings for FFG36-61 are also used. As mentioned in Chapter 2, these ships (FFG36-61) are of greater displacement than FFG7-35. FFG36-61 also have heavier scantlings near the keel and shear strake from stations 9 through 13. The longitudinal strength drawings present a graphical representation of the longitudinal weight distribution for FFG36-61 in the full load condition. The weight is described by values in units of long tons (ltons) per foot between each of stations 0 through 20. The weight of the ship forward of the forward perpendicular and aft of the aft perpendicular is also included. The weight values are assumed constant between stations.

The full load displacement mentioned on the more generic FFG36-61 strength drawings is slightly lower than the full load displacement in the FFG61 weight report (3914 ltons vs. 3987 ltons). To reconcile this slight discrepancy, the strength drawing full load weight distribution values are scaled proportionally so that the full load total weight is that of the FFG61. The final step is to convert the ltons per foot values to ltons. This is done by multiplying the ltons per foot values by the appropriate station spacing. The result is used as input to the Ship Hull Characteristics Program (SHCP). Appendix A contains spreadsheets that show both the full load longitudinal weight distribution and the weight distribution for conditions less than full load.

The next three steps are the computation of longitudinal buoyancy, shear, and moment distribution. The Ship Hull Characteristics Program (SHCP) is used for these steps. SHCP is the US Navy's standard hydrostatics program. The primary input is a numerical description of the hullform using a set of hull offsets. SHCP contains subprograms that perform such naval architectural calculations as trim lines, longitudinal strength, floodable length, and intact stability.[16]

The longitudinal strength module of SHCP is used to derive the longitudinal moment distribution in all load and seastate variations studied. Figure 4-1 is a body plan generated by SHCP using the offsets for FFG36-61. Figure 4-2 presents an isometric view of the hull as modelled.

The longitudinal strength module of SHCP calculates a longitudinal hydrostatic buoyancy distribution using the longitudinal weight distribution and the hull offsets. SHCP calculates the longitudinal center of gravity (LCG) and displacement from the given weight distribution. The program next calculates the draft and trim corresponding to this LCG and displacement. SHCP determines the buoyancy for each section of the hull between stations. The net load on each section is the difference between the buoyancy and the weight. SHCP integrates the load longitudinally to determine the shear

[16]Ship Hull Characteristics Program Users Manual, CASDAC #231072, NAVSEC 6133E/6105B, January 1976, p. I-1.

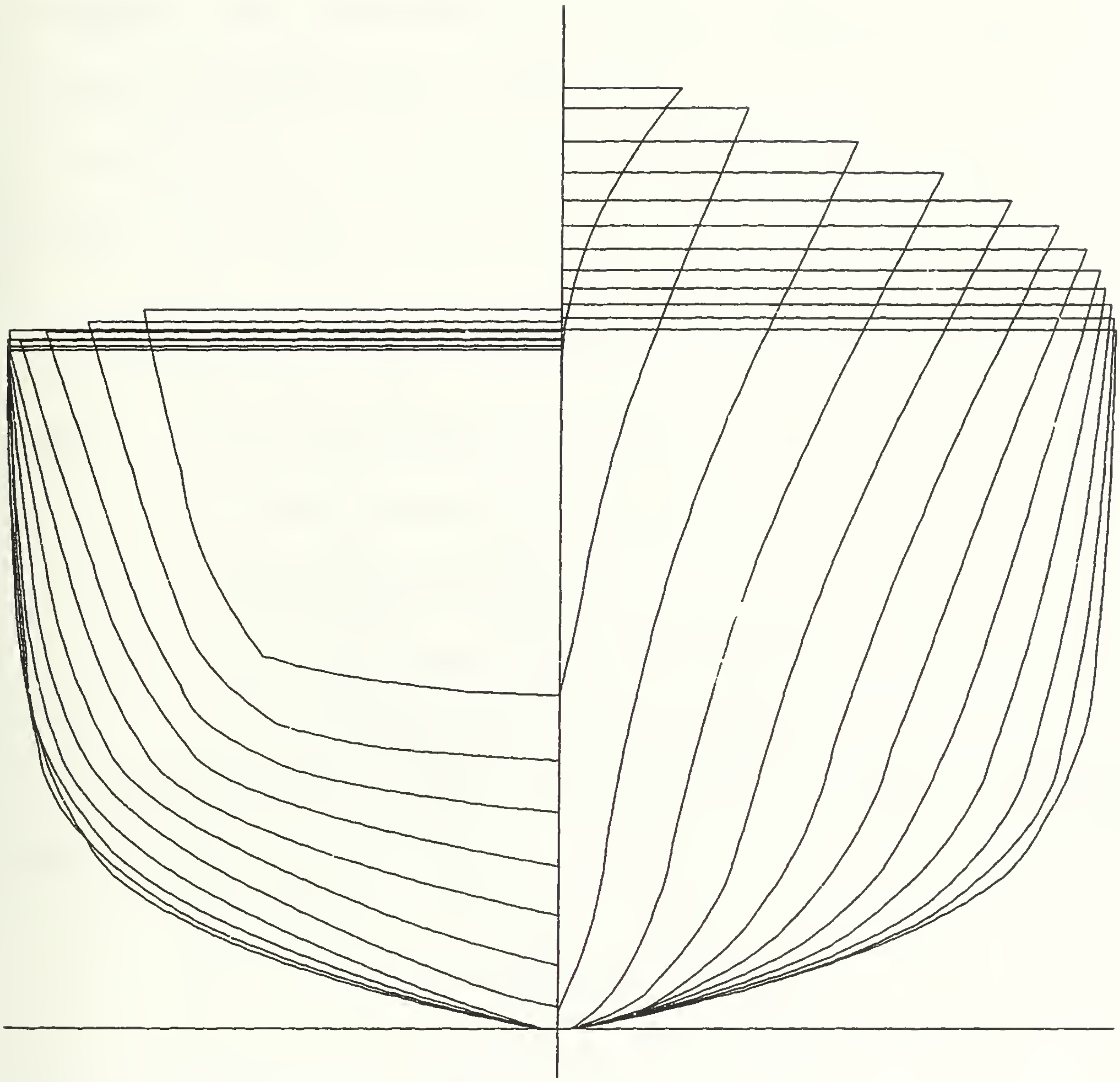

Figure 4-1: SHCP Body Plan of FFG36-61

at each station. The shear is then integrated to determine the bending moment at each station.

The SHCP longitudinal strength module output consists of a file containing an input summary and values for buoyancy, shear, and moment organized by station. SHCP also provides graphical representations of these data. Appendix B contains the SHCP output files showing the shear and bending moment values for each condition. The

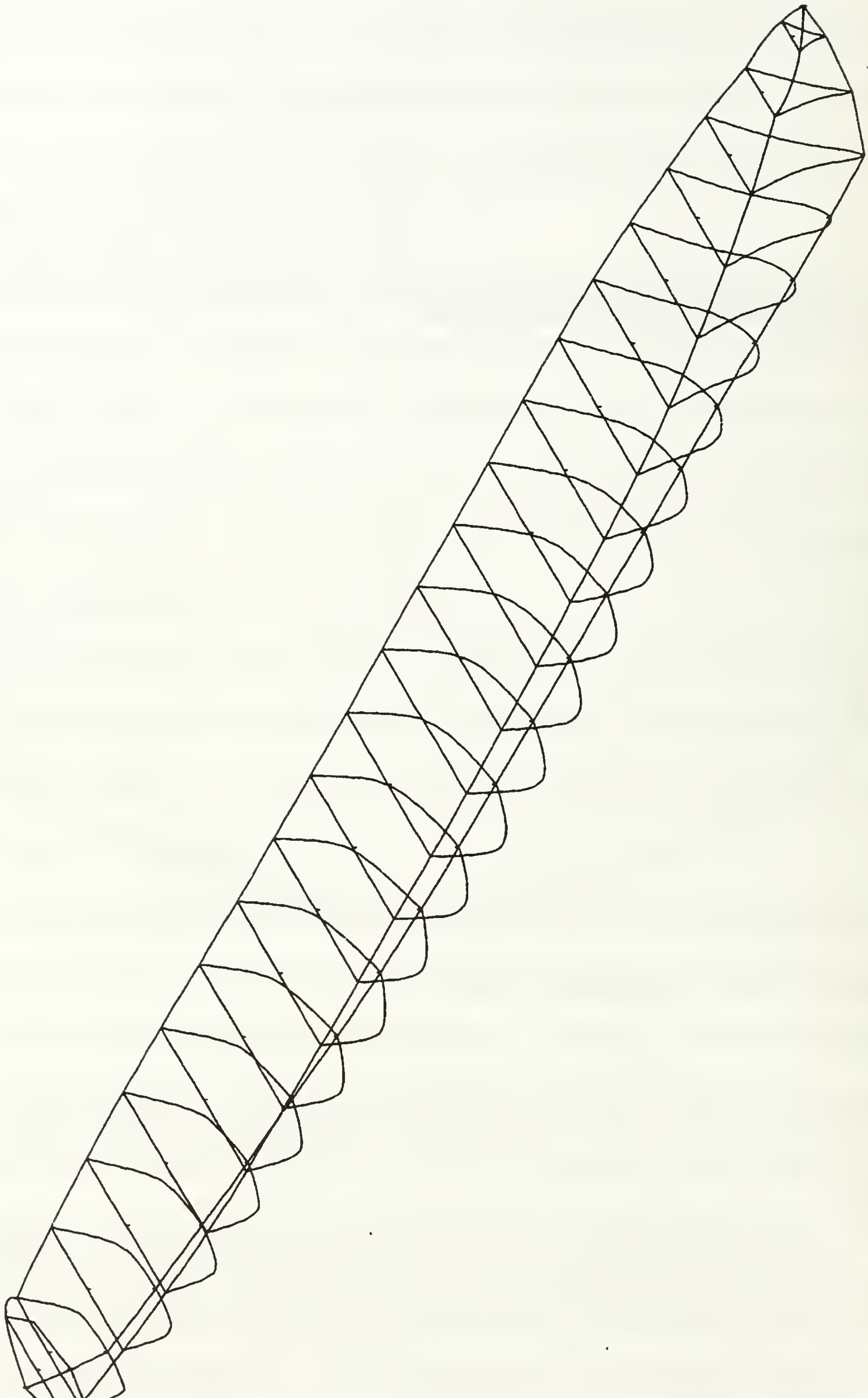

Figure 4-2: SHCP Isometric View of FFG36-61

graphic SHCP output is also included in Appendix B. The moment values at each station are used in the remainder of the calculations.

Simple beam theory is now applied to derive the hull deflection. The differential equation for the elastic curve of a beam is

$$\frac{\partial^2 y}{\partial x^2}=\frac{M(x)}{EI(x)} \tag{1}$$

where: x = length along the beam's axis

y = deflection perpendicular to the axis

M(x) = moment along the axis

I(x) = area moment of inertia of beam section

E = modulus of elasticity of beam material

Integrating this equation twice gives an expression for the deflection at any point along the x-axis of the beam:

$$\frac{\partial y}{\partial x}=\frac{1}{E}\int_0^d \frac{M(x)}{I(x)}\partial x+a \tag{2}$$

$$y(d)=\frac{1}{E}\int_0^d\int_0^d \frac{M(x)}{I(x)}\partial x\partial x+ad+b \tag{3}$$

where: d = distance along x-axis

The hull girder can be assumed to flex relative to a straight line between the forward and aft ends. The deflections at these points are zero.

$$y(0,L)=0 \tag{4}$$

Applying these boundary conditions allows one to solve for the constants of integration:

$$a=-\frac{1}{EL}\int_0^L\int_0^L\frac{M(x)}{I(x)}\partial x\partial x \tag{5}$$

$$b=0 \tag{6}$$

The final equation for the deflection of a beam of length L simply supported at each end is:

$$y(d)=\frac{1}{E}\int_0^d\int_0^d\frac{M(x)}{I(x)}\partial x\partial x-\frac{d}{LE}\int_0^L\int_0^L\frac{M(x)}{I(x)}\partial x\partial x \tag{7}$$

The integrations are performed using the trapezoidal rule approximation on a station-by-station basis. Between each station the appropriate values for the bending moment and moment of inertia are used. Because the hull material is constructed entirely of steel, a constant value, 13,400 ltons/in^2, is used for the modulus of elasticity.[17]

Following the previously described procedure results in the still water deflection for the FFG61 in full load condition. To investigate the effects of altering the loading condition, three other load conditions are checked. They are:

1) full load except for an 80 percent fuel load,

2) full load except for a 60 percent fuel load, and

3) minimum operating condition.

The hull flexure is calculated for a condition of all loads at full load except for fuel, which is at 80% of full load. This second load condition depicts a probable

[17]"Longitudinal Strength Calculations", Design Data Sheet (DDS) 2900-1-q, Department of the Navy, 27 December 1950.

operational condition. Fuel is the only load item of any significant weight to fluctuate during routine operations. Warships typically operate with replenishment vessels and take on fuel and stores often. Frigates will usually refuel when close to the point of 80% fuel remaining.

The fuel is next reduced to 60% of full load. This condition is a realistic lower limit for actual operational conditions. US Navy ships will rarely go below the 60% fuel point. As with the 80% fuel condition, all loads except ship's fuel are left at their full load values. Ballast seawater is added at the 60% fuel condition. This is discussed later in this chapter.

The minimum operating condition is used as a lower limit for load conditions. Minimum operating condition, or Condition B, is a load condition both recognized and well defined by the US Navy. Appendix A shows how the various loads are adjusted for the minimum operating condition.[18]

The minimum operating condition is often used for stability predictions. For this reason, items typically stored high on the ship (missiles, torpedoes, depth charges, and aircraft) are at their full load values. Most of the other load items (i.e., aircraft and ship fuel, lube oil, provisions, and ammunition) are at one-third of their full load values in the minimum operating condition.[19]

The minimum operating condition denotes a worst case load condition from an operational standpoint. A US Navy frigate at sea would rarely, if ever, reach the minimum operating condition.

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[18]Naval Ship's Technical Manual, Chapter 096 "Weights and Stability", NAVSEA S9086-C6-STM-000, 15 February 1976, p.19.

[19]Ibid.

The FFG7 class has fuel oil storage tanks distributed longitudinally from frame 56 to frame 250. How fuel is distributed between these tanks influences the hull deflection. Each class of US Navy ship is provided with fuel and ballast sequence tables. These inform the crew as to what order fuel and ballast tanks should be used. The fuel and ballast sequence tables for the FFG7 class are used for determining the fuel and ballast distributions for the conditions involving fuel amounts below that of full load.

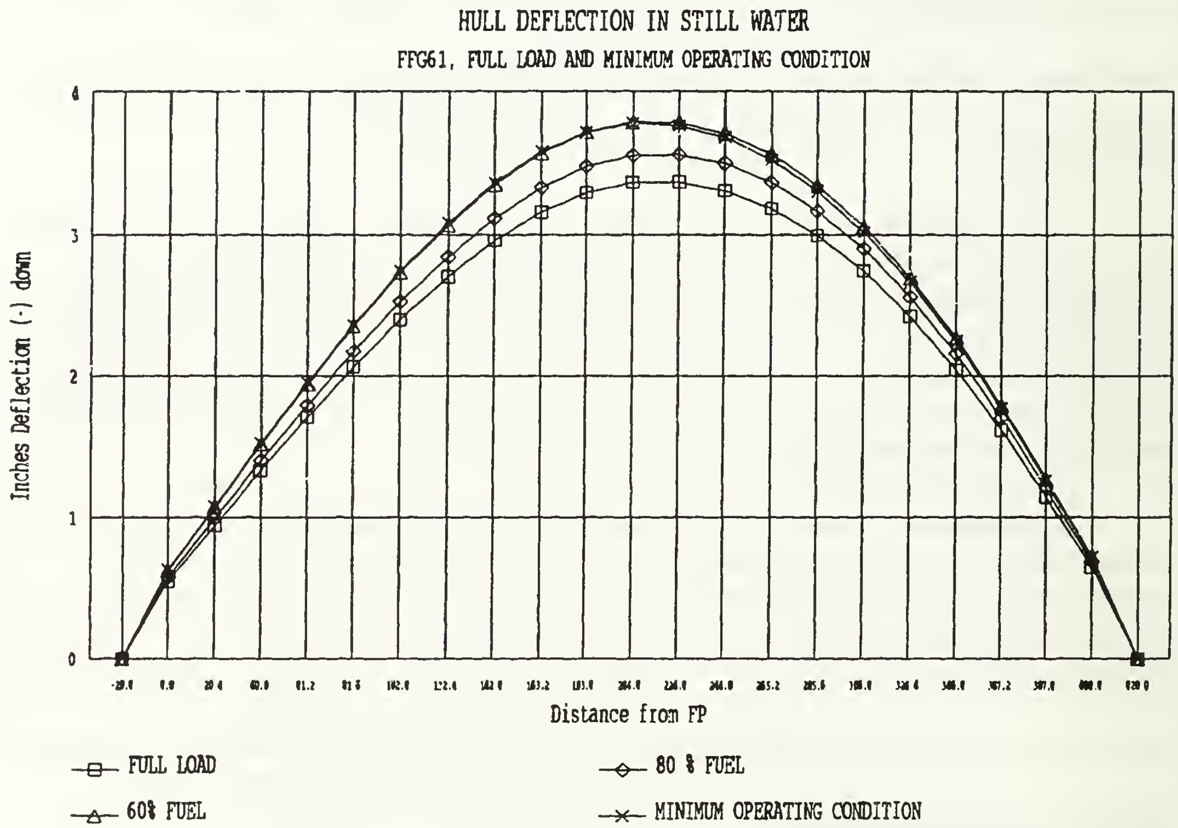

Figure 4-3: Hull Deflections for Full Load, 80% Fuel, 60% Fuel, and Min. Ops.

The calculations for the hull deflections, starting with the SHCP generated moment distributions, are included in Appendix C. Figure 4-3 presents a summary of the hull deflections for the full load, 80% fuel, 60% fuel, and minimum operating conditions. The FFG61 is in a hogging condition at full load. This can be predicted by examining the

SHCP plot of weight and buoyancy distribution for the full load still water condition included in Appendix B. The hogging condition increases at the 80% load, 60% load, and minimum operating condition. This is primarily because the larger fuel tanks are located towards amidship. These fuel tanks amidship are also the first to be emptied, as dictated in the FFG7 fuel and ballast sequence tables.

The 60% load and minimum operating condition result in similar deflections. This is because the primary load item is ship's fuel. As fuel is reduced from 60% to the 33% specified for the minimum operating condition, seawater ballast is added to empty fuel tanks. This results in only a small change in weight and its longitudinal distribution.

No seawater ballast is specified at the full load or 80% fuel conditions. At the 60% fuel condition two ballast tanks are full. At minimum operating condition eight tanks are full of seawater ballast. These eight tanks include all four of the ship's dedicated seawater ballast tanks. Some of these ballast tanks are towards the ends of the ship, thus further contributing to the higher hogging deflections at the 60% fuel and minimum operating condition.

The eight tanks containing ballast water at minimum operating condition include four fuel tanks that were emptied as fuel was consumed. Ballast water placed in empty fuel tanks is referred to as dirty ballast. Operators are very hesitant to use fuel tanks for ballast, even when doing so is specified for stability reasons. The ballast water inevitably contains some fuel which is discharged overboard when the tanks are emptied. There are also small amounts of seawater that remain in the fuel tanks and can contaminate the next load of fuel. The fuel and ballast sequence tables recommend that dirty ballast commence at a point when approximately 60% of the ship's fuel is remaining. Below the point of about 40% fuel remaining, only dirty ballast tanks remain to be filled. The 60% fuel condition represents the lowest fuel load attainable without resorting to using dirty ballast, as prescribed by the fuel and ballast sequencing tables.

5. Hull Deflections Due to Wave Induced Bending Moment

Analyzing hull deflections due to wave induced bending moments involves the basic steps presented at the beginning of Chapter 4. Instead of varying the load conditions, the hull is superimposed on a wave profile of varying height. Wave stresses are low-frequency dynamic loads that result in negligible dynamic amplification. This neglects any effects of slamming and hull whipping.

Wave primary stresses in the hull girder are often examined using quasi-static methods. Typically, the ship is considered in a state of static equilibrium on either the trough or the crest of a wave. The wavelength is usually taken as equal to the ship's length to achieve the maximum effect on hull bending moment. As in a still water case, the weight of water displaced by the hull equals the ship's weight. The longitudinal buoyancy distribution is calculated using the wave surface instead of the still water draft. The computations for load, shear, and moment distribution are identical to those for the still water condition.

SHCP uses the quasi-static method to calculate longitudinal distributions of hull bending moment in waves. Various combinations of wavelength, height, and longitudinal position can be specified. Regular trochiodal waves are used. For each wave profile, SHCP determines the draft that results in the correct displacement.

The quasi-static approach is an approximate method. It neglects the motions of the vessel and the hydrodynamic pressures between the hull and waves. Experimental data has shown the quasi-static method tends to overestimate the bending moments caused by waves.[20]

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[20] Principles of Naval Architecture, Vol. I, pp. 212-3.

A standard for US Navy hull structural design is the wave stress from a wave of height equal to $1.1\sqrt{LBP}$[21]. For the FFG7, this results in a wave height of 22.2 feet for initial hull strength design criteria. It was decided to examine the effects of waves having heights equal to the mean values of the significant wave heights for seastates 2, 4, and 6. Seastate 6 has a average significant wave height of 16.4 feet. This is considered a sensible upper limit for purposes of evaluating the effects on combat system alignment. At seastates in this region, a frigate's ability to fight is degraded from other causes. Ship motions at these higher seastates make conducting combat operations extremely difficult. Warships of frigate dimensions are typically required only to maintain mobility and maneuverability in higher seastates.

Table 5-1: Seastate 2, 4, and 6 Characteristics in North Atlantic

SEASTATE NUMBER	AVERAGE SIGNIFICANT WAVE HEIGHT, ft.	MODAL WAVE PERIOD, T sec.		WAVELENGTH, BASED ON $L=5.118T^2$ ft.	
		MOST PROBABLE	RANGE	MOST PROBABLE	RANGE
2	1.0	7.5	3.3-12.8	288	56-839
4	6.2	8.8	6.1-15.2	396	190-1182
6	16.4	12.4	9.8-16.2	787	492-1343

Table 5-1[22] contains statistical data on seastate occurrences in the North Atlantic. It must be noted that actual sea conditions are not usually the regular trochoidal

[21]"Longitudinal Strength Calculations", Design Data Sheet (DDS) 2900-1-q.

[22]Principles of Naval Architecture, Vol. III, p.28.

waves that SHCP uses in its quasi-static analysis. Actual sea conditions are irregular and better represented by a spectrum of frequencies. To use such a spectral representation of the sea for these purposes would be beyond the scope of this thesis. The quasi-static method using regular trochoidal waves will yield results that are accurate enough to be of value.

A constant wavelength equal to the FFG7's LBP is used. Similar to using regular waves, using a constant value for the wavelength is a practice that simplifies the character of actual ocean waves. It is a simplification that will provide conservative results. A wave of any height will have a maximum effect on bending moment when its length is the same as that of the ship.

The SHCP output for the analyses of the ship in waves are included in Appendix B. The output lists tabular values for both the quasi-static buoyancy and the shear and bending moments. Each SHCP output file contains both hogging and sagging calculations for one wave height. The SHCP graphic output depicts the actual wave profile as well as the buoyancy, shear, and moment distributions. Figure 5-1 shows the hull deflection from the full load condition in seastates 0, 4, and 6. The deflections for seastate 2 are not included in Figure 5-1 because they are not appreciably different from the deflection at still water. It must be remembered that the deflections shown in Figure 5-1 are due to wave action and are dynamic with respect to the seastate 0 deflection. An interesting observation is that the hull experiences a true sagging moment only in the trough of a wave of seastate 6 height. As discussed in Chapter 4, this is due to the still water hogging condition of the ship.

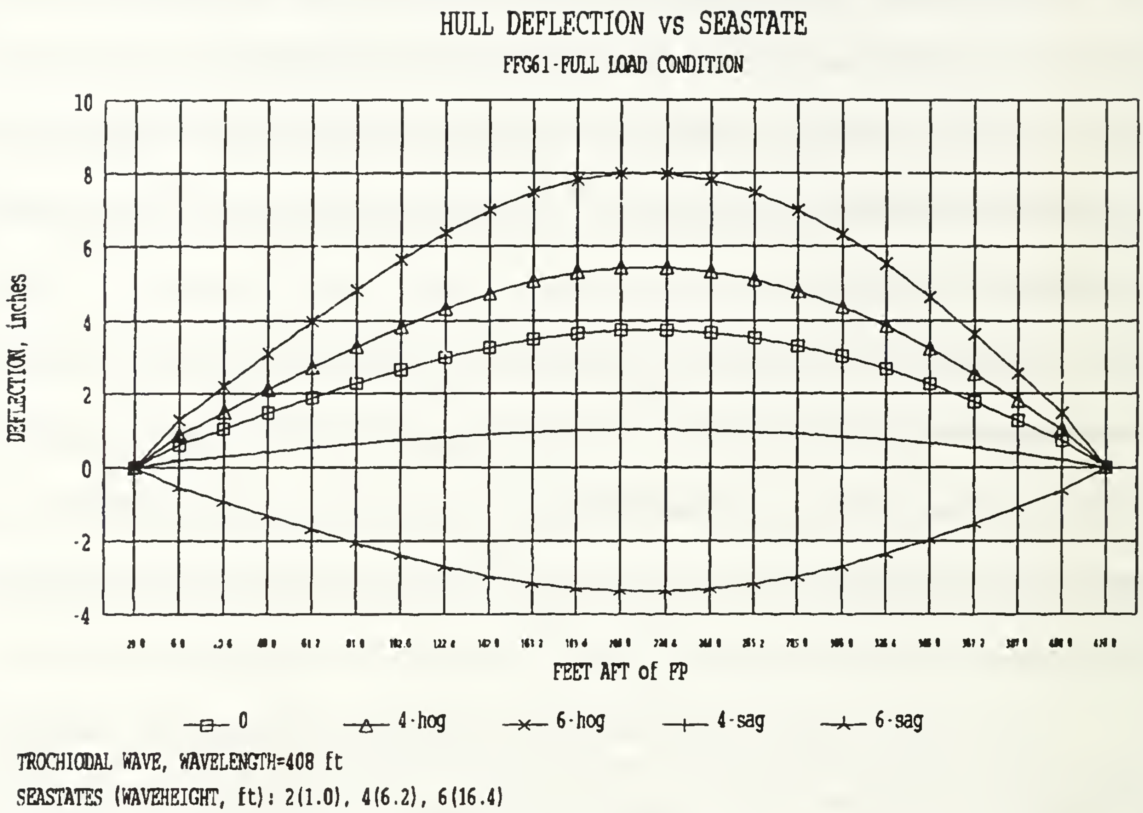

Figure 5-1: Full Load Deflections in Seastates 0, 4, and 6

6. Effects on Combat System Alignment

The vertical deflections caused by load variations and seastate (Figure 4-3 and Figure 5-1) do not directly effect the combat system alignment. The maximum deflection from the full load still water condition calculated is about 6.6 inches in the seastate 6 sagging condition. What could pose a problem for the combat system alignment is the rotation between combat system components due to the hull deflection. As described in Chapter 3, all alignments are specified in minutes of arc. The angular displacement between the combat system components must be calculated to assess the impact of load variations and seastate on combat system alignment.

The steps taken in assessing the angular displacements are as follows:

1. Fit a curve to the displacements calculated in Chapters 4 and 5.
2. Take the derivative of the curve.
3. Use the derivative to obtain values for the slope of the hull at various longitudinal locations. Convert slopes to minutes of arc units.
4. Determine amount of rotation between various elements in combat system.
5. Evaluate these inter-element rotations relative to the full load condition.

This procedure has been used successfully by at least one shipyard for determining if a vessel complies with the intent of the 80% and 90% displacement requirements at the time of combat system alignment.[23]

The first step is to fit a curve to the calculated displacements. A fourth order polynomial is used for this purpose. The polynomial has the form

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[23] P. Lacey, "Battery Alignment Hull Deflection Method", Department 86NA, Bath Iron Works, 24 July 1989.

$$y = C + Dx + Ex^2 + Fx^3 + Gx^4 \tag{8}$$

The coefficients in Equation (8), C, D, E, and F, are computed so the resulting polynomial will provide a least squares fit. The coefficients are found using the following matrix operations:

$$A = \begin{vmatrix} 1 & x_0 & x_0^2 & x_0^3 & x_0^4 \\ 1 & x_1 & x_1^2 & x_1^3 & x_1^4 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & x_n & x_n^2 & x_n^3 & x_n^4 \end{vmatrix} \qquad U = \begin{vmatrix} C \\ D \\ E \\ F \\ G \end{vmatrix} \qquad b = \begin{vmatrix} b_0 \\ b_1 \\ \cdot \\ \cdot \\ \cdot \\ b_n \end{vmatrix}$$

where $x_1, x_2, \ldots, x_n$ = longitudinal locations where deflections are calculated

$b_1, b_2, \ldots, b_n$ = calculated displacement values at locations $x_1, x_2, \ldots, x_n$

The matrix U containing the coefficients for Equation (8) is computed by the following group of operations involving matrices A and **b**.

$$U = (A^T A)^{-1} A^T b \tag{9}$$

where A^T = the transpose of matrix A

$(A^T A)^{-1}$ = the inverse of the matrix product of A^T and A

The resulting matrix U contains the coefficients for the least squares fourth order polynomial curve. The actual matrix calculations are done on spreadsheets. The curve coefficients for each case are included in Appendix C.

The remaining steps in the calculations are straightforward. The spreadsheets in Appendix C show slopes and rotations in minutes of arc for the following components of the combat system:

Mk 13 Missile Launcher	(70 feet aft FP)
CAS Fire Control Radar Antennae	(120 feet aft FP)
STIR Fire Control Illuminator	(208 feet aft FP)
Mk 75 Gun	(240 feet aft FP)

These items were selected for analysis for two reasons. First, the Mk 13 and Mk 75 represent fore and aft limits of the FFG7's combat system. Second, they all are components associated with the fire control system and have relatively tight alignment tolerances. Other longitudinal locations can be investigated by using the derivatives of the appropriate deflection curves in Appendix C.

Table 6-1 shows the effects of the load variations on the inter-element alignment relative to the full load condition. It is assumed that the combat system is initially aligned when the ship is at full load. The still water deflection present in the full load condition would be taken into account during the alignment procedure. For this reason, Table 6-1 presents inter-element rotations relative to the full load state.

The rotations shown in Table 6-1 are largely influenced by the elements' longitudinal separation. The Mk 13 launcher and the Mk 75 gun show the largest rotation because they are the elements farthest away from each other. Likewise, the CAS and the Mk 13 are relatively close longitudinally and the alignment between them is not affected as much by hull flexure.

Table 6-1: Load Condition Effects on Inter-Element Alignment

Combat System Element Pairs (not all element pairs shown)	Rotation Between Elements of Combat System Relative to Full Load at Specified Load Condition in arc-minutes		
	80% Fuel Condition	60% Fuel Condition	Minimum Operating Condition
Mk 75 - STIR	0.13	0.22	0.22
Mk 75 - CAS	0.41	0.80	0.84
Mk 75 - Mk 13	0.50	1.05	1.14
STIR - CAS	0.28	0.58	0.62
STIR - Mk 13	0.37	0.83	0.92
CAS - Mk 13	0.09	0.25	0.29

The inter-element rotational displacements are determined for the wave induced deflection cases using the procedure previously described. Figure 6-1 shows the inter-element rotations of the Mk 13, CAS, STIR, and Mk75 at seastates 0, 2, 4, and 6. As with the rotations in Table 6-1, those in Figure 6-1 are relative to the baseline full load seastate 0 condition. It must be remembered that the deflections caused by wave action are dynamic while those caused by load variations are effectively static. For example, the alignment between the CAS and the STIR in seastate 4 would be varying from -2.3 to +2.2 arc minutes as the vessel passes from wave crest to trough.

Comparing the magnitudes of the deflections in Table 6-1 with Figure 6-1 indicates that the deflections caused by seastate can be much more severe than those caused by load variations. The hull deflection caused from varying the load from full load to minimum operating condition is similar to the deflection caused by a wave

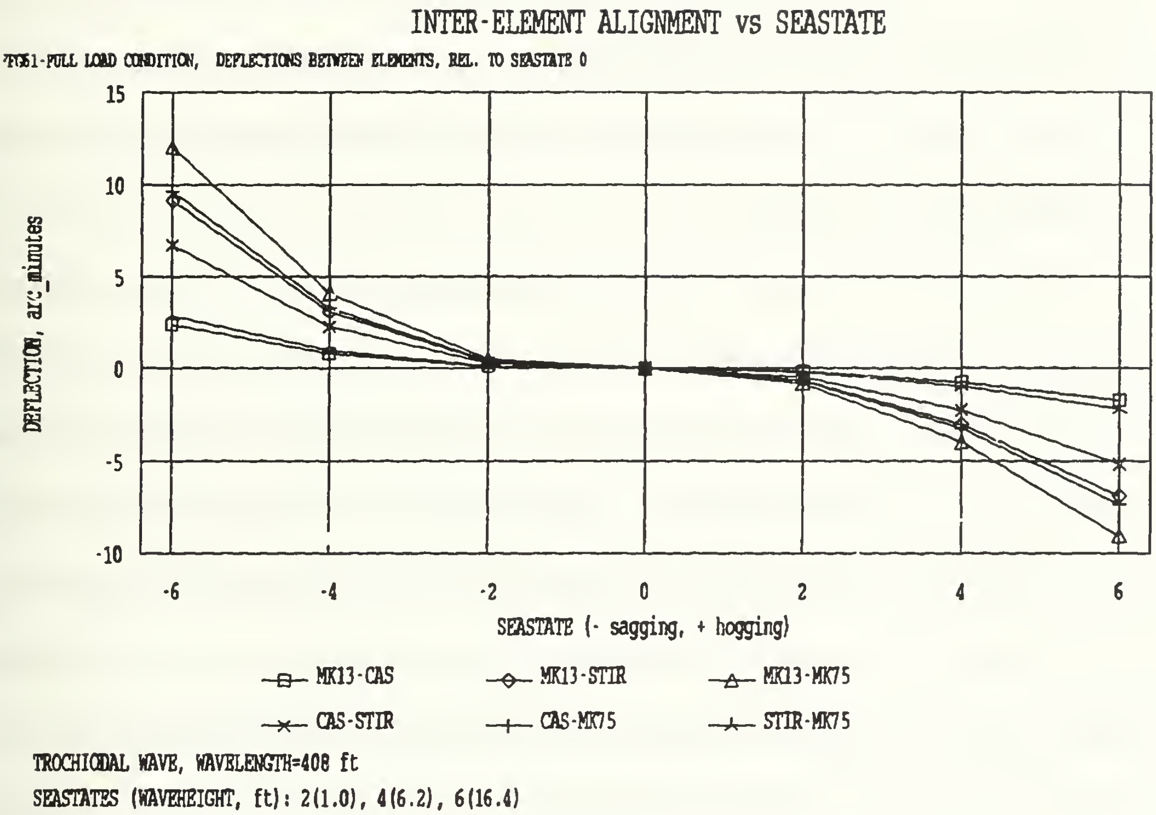

Figure 6-1: Inter-Element Alignment at Seastates 0, 2, 4, and 6

slightly larger than the seastate 2 wave height used, about 2 feet.

It was initially intended to run combinations of load variations and seastates in order to obtain a matrix of results. The difference in magnitudes between the effects of the two indicated that this effort would be unproductive. A frigate is much more likely to encounter a seastate in the 4-6 range than it is in obtaining a minimum operating load condition.

The rotations calculated for both the load conditions and the seastate conditions are in the vertical centerline plane. The effects that the predicted rotations will have on the combat system will depend on the actual train and elevation to which the elements are directed. If, for example, the Mk 75 gun and the Mk 13 missile launcher are both trained to 90° (from the bow) and at zero elevation, then the rotations previously described will be along the pointing lines of the gun and launcher and will not effect the alignment. As the train deviates from 90° and/or the elevation angle increases from zero, the effects become pronounced.

The load variations examined have an insignificant effect on combat system alignment. The highest inter-element deflection is 1.14 arc minutes between the Mk 75 gun and the Mk 13 missile launcher. This is well within the gun's operational roller path inclination tolerance of ±3 arc minutes. Additionally, there is no actual need for the gun and the missile launcher to be precisely aligned. They are both directionally steered by the Mk 92 fire control system. The Mk 92 fire control system relies on the CAS, STIR, and WSN-2 gyrocompass for bearing and elevation input. It then feeds this information to the gun and launcher. The most demanding tolerance is for the WSN-2 gyrocompass and is ±1 arc minute for its operational roller path inclination. Since the CAS, STIR, and WSN-2 are longitudinally between the gun and missile launcher, the relative roller plane inclinations for "drive-driven" combinations of elements will be less than one minute of arc.

The effects of load variations on alignment becomes even less significant when one considers how infrequently a frigate attains a load case like the 60% fuel or minimum operating condition. The 80% fuel condition examined represents a much more realistic fluctuation from full load. At the 80% fuel condition, the relative inter-element inclinations are about one-half of the inclinations at the 60% fuel and minimum operating condition.

The effects of seastate on combat systems alignment are more significant than the effects of load variations. As previously mentioned, the element with the most demanding alignment tolerance is the WSN-2 gyrocompass at ±1 arc minute. The CAS and STIR radars have a tolerance of ±2 arc minutes. The Mk 75 gun has an elevation tolerance of ±2 arc minutes and a RPI tolerance of ±3 arc minutes. As shown in Figure 6-1, only pairs of elements very close to each other (Mk 13-CAS, STIR-Mk 75) have relative deflections of less than ±1 arc minute at seastate 4. Other combinations (CAS-STIR, Mk 13-STIR, and CAS-Mk 75) and are in the range of ±2 to ±3 arc minutes at seastate 4. This amount of rotation is at the limits of the RPI tolerances for these elements.

There are several operational consequences of the combat system components being out of alignment. The gun could be misaligned with its controlling radar. In the FFG 7 class the CAS performs both search and track functions for the Mk 92 fire control system. The gun could also be misaligned with the WSN-2 gyrocompass. The gun is depending on the gyrocompass for roll and pitch stabilization and the actual aim point would be fluctuating about the desired target. Both the WSN-2 and the CAS are longitudinally far from the gun. This amplifies the effects of any hull flexure.[24]

Ships with different combat systems can experience other problems. Many modern US Navy destroyers and cruisers depend on the accurate pointing of radar target illuminators for AAW engagements. The illuminators have a very narrow beamwidth and are aimed at the target by a separate tracking radar. Misalignment between the track

[24]"Combat Systems Engineering in Ship Design", Vol. 1, General Electric, Government Electronic Systems Division, Moorestown, New Jersey, p. GA-17.

radar and the illuminator could cause an in flight missile to loose its guidance signal. The FFG7's missile fire control illuminator, the STIR, has its own tracking capability and does not depend on another radar for train and elevation information once it has acquired a target. Precision remote electro-optical target designation devices also are sensitive to alignment variables. The FFG7 class uses an manual optical target designation transmitter for gun fire control, but it is not as sensitive as newer automated systems. The SPY-1D phased array radar system aboard the CG47 class cruiser is sensitive to having the array faces, which are mounted on separate deckhouses, maintaining alignment with respect to each other. The newer cruisers and destroyers also carry more modern AAW missiles having inertial reference units for midcourse guidance. These units are also sensitive to alignment.[25]

At seastate 6 all element combinations examined are outside of ±2 arc minutes of deflection relative to calm water. Two combinations, Mk13-STIR and Mk 75-CAS, are in the ±7 to ±10 arc minute range. This is well outside the RPI tolerances for all of these elements except the Mk 13 launcher. The launcher does have a ±5 arc minute tolerance for elevation alignment which is exceeded.

The element combination with the most severe relative deflection, the Mk 75 gun aft and Mk13 launcher forward, is not considered as significant as gun-radar or launcher-radar combinations. This is because the gun and launcher lack any direct functional relationship, i.e., one does not direct the other. This is taking a different approach than the alignment procedure, described in Chapter 3, takes. The alignment procedure uses the Mk 75 gun's roller path plane as the reference plane for aligning all

[25]"Combat Systems Engineering in Ship Design", Vol. 1, p.GA-17.

other elements. After an alignment, we are more concerned with how various factors degrade the operability of the system. To do this, the interdependence of the combat system components must be considered.

7. Conclusions

It has been shown that load variations do not significantly affect the operational alignment of the combat system of the FFG61. These results should apply to all of the LAMPS III equipped frigates in the class (FFG8, FFG36-61). Fuel is the only major load item that typically varies. Since the LAMPS I versions of the FFG7 class have similar fuel capacities, it follows that these results should also apply to the LAMPS I versions as well.

The effect of waves are also calculated. The results indicate that the waves cause enough flexure in the hull to be of concern. At seastate 4, the inter-element alignment fluctuates with magnitudes near the alignment tolerance for several of the components. At seastate 6, hull deflections result in misalignments on the order of 9 arc minutes between the CAS and Mk 75 gun and between the STIR and Mk 13 launcher. This exceeds the elements' individual operational roller path inclination and operational elevation alignment tolerances.

There are several assumptions made in determining the wave induced hull bending moments. One assumption involves the use of the quasi-static method. As mentioned in Chapter 5, the quasi-static method tends to overestimate the wave induced bending moment somewhat. It neglects ship motion and hydrodynamic pressures on the hull. A second assumption consists of the use of regular waves of length equal to LBP. Like the quasi-static method, the use of regular waves of length equal to LBP represents a conservative simplification of a complex situation.

A possibility for future research in this area would be to conduct a study on the effects of waves using a program based on strip theory. Strip theory would result in a more accurate prediction of the moment distribution along the hull girder. This approach could also be combined with a statistical representation of waves at various seastates. Together, these two refinements would yield more accurate results.

This thesis does not attempt to account for misalignment due to deflections in masts, equipment supporting structures, and/or the ship's superstructure. The analysis of these structures would be best handled by finite element methods.

This thesis also omits the effects of structural distortions caused by temperature differences. Thermal distortions can affect the hull girder, the superstructure, and individual equipment foundations. When a hull encounters both cool water and warm air it will tend to hog. This flexure would add to the flexure caused by fuel being consumed. The combination may be significant. The combination of thermal effects and wave effects should not be of concern because extreme thermal deflections would typically not occur in unison with high seastates. Finite element analysis would be required to assess thermal effects.

The Ship Specifications for the DDG51 class of destroyer, the US Navy's most modern surface combatant, requires the computation of inter-element alignment variances for changes in loading, sea and air temperature, and wind speed. Based on the findings of this study, the effects of seastate should be included in this requirement.

The general US Navy requirements specifying a minimum vessel displacement for alignment purposes, mentioned in Chapter 1, are not effective. The intent is to insure that the hull is in a state of deflection during alignment that is similar to that at full load condition. For the FFG61, the displacement at minimum operating condition is 96% of the displacement at full load. The loads at minimum operating condition are reasonably distributed because much of the consumed fuel is replaced by ballasting empty fuel tanks. If the displacement is only at the 80% full load specification, whether from the absence of loads or the removal of lightship items, the weight distribution could be considerably different than those analyzed in this thesis. Many load items are removed when a vessel is in a shipyard for repair or overhaul. Shipyard equipment on board also affects the weight distribution. It is possible to comply with the letter of this requirement without complying with the intent of the requirement.

During new construction combat system testing and checkout is usually done concurrently with the final stages of outfitting. Scheduling difficulties often necessitate conducting alignment procedures before the ship is near the full load condition. In this circumstance it would be possible to use the method presented to predict the flexure of the hull as compared to the flexure at full load condition. The differences could be included in the alignment process. As a result, the combat system would approach its desired alignment condition as the ship approaches the full load condition.

Modern naval combat systems have strict alignment tolerances. There is little that can be done to remedy the alignment problems mentioned after a ship is built. It would be beneficial to analyze potential problems with combat system alignment during contract design to ensure against compromising the combat system effectiveness in the conditions specified by the Top Level Requirements.

Appendix A: Longitudinal Weight Distributions

The spreadsheets in this Appendix A present the loads in the FFG61 Final Weight report in a tabular form. The full load condition is presented in the second column. If less than full load is desired, the adjustments can be entered, as a percentage of full load, in the third column. Ballast can be added in a similar fashion. If a load item has a capacity load (i.e., tanks) which is higher than its full load value, the capacity load is used for the percentage. The second portion of each spreadsheet computes a full load longitudinal 20-station weight distribution based on the FFG36-61 Longitudinal Strength Drawing. For less than full load conditions, the weight distribution by longitudinal section is adjusted accordingly.

FFG61 LOADS AND LCG's ** FULL LOAD AND 80% FUEL CONDITION **

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
OFFICERS, CREW, & EFFECTS		24.39	100%	24.39	0.00	54.2	149.8
TORPEDOES IN TUBES		1.36	100%	1.36	0.00	-8.9	212.9
MISSILES		24.55	100%	24.55	0.00	130.0	74.0
76mm IN MOUNT & MAG.		11.29	100%	11.29	0.00	-36.0	240.0
SMALL ARMS		3.15	100%	3.15	0.00	143.0	61.0
CIWS IN MOUNT AND MAG.		4.93	100%	4.93	0.00	-107.0	311.0
TORPEDOES IN MAG.		4.08	100%	4.08	0.00	-23.0	227.0
SONOBOUYS		4.29	100%	4.29	0.00	-74.0	278.0
CAD (CARTRIDGE ACTV. DEV.)		0.75	100%	0.75	0.00	153.0	51.0
OTHER		0.75	100%	0.75	0.00	-45.0	249.0
LAMPS III HELOS		15.91	100%	15.91	0.00	-96.0	300.0
HELO SUPPORT		5.10	100%	5.10	0.00	-135.0	339.0
HELO SPARES/MAINT.		3.14	100%	3.14	0.00	-61.0	265.0
HELO OP. FLUIDS		1.17	100%	1.17	0.00	25.3	178.7
DRY, CHILL, & FREEZE PROV.		23.58	100%	23.58	0.00	13.0	191.0
SHIP'S STORE STRM		3.49	100%	3.49	0.00	4.0	200.0
SMALL STORES		0.31	100%	0.31	0.00	146.0	58.0
GENERAL STORES, FWD		10.52	100%	10.52	0.00	160.0	44.0
GEN STORES, AFT		8.21	100%	8.21	0.00	-155.0	359.0
** LIQUID LOADS **							
POTABLE WATER							
5-292-2&3 W		17.44	100%	17.44	0.00	-94.0	298.0
5-308-1&2 W		15.76	100%	15.76	0.00	-116.0	320.0
COLLECTING & HOLDING TANK							
4-170-0 W	2.96	0.00	100%	2.96	2.96	30.1	173.9
LUBE OIL STORAGE							
3-272-2 F		3.50	100%	3.50	0.00	-70.6	274.6
3-278-2 F		4.00	100%	4.00	0.00	-78.0	282.0
3-286-2 F		2.75	100%	2.75	0.00	-85.1	289.1
SSGD LUBE OIL							
4-208-2 F		0.95	100%	0.95	0.00	-6.3	210.3
3-236-1&2 F		2.10	100%	2.10	0.00	-34.3	238.3
3-292-8 F		0.92	100%	0.92	0.00	-89.1	293.1
LUBE OIL SETTLING							
3-278-1 F	3.58	0.00	100%	3.58	3.58	-77.9	281.9
3-286-1 F	2.42	0.00	100%	2.42	2.42	-84.7	288.7
DIESEL OIL STORAGE							
5-56-0 F		14.83	100%	14.83	0.00	143.9	60.1
5-64-0 F		42.05	100%	42.05	0.00	129.6	74.4
5-84-1&2 F		112.74	100%	112.74	0.00	111.8	92.2
5-100-3&4 F		65.40	66%	43.16	-22.24	92.3	111.7
5-116-1&2 F		133.72	100%	133.72	0.00	75.6	128.4
5-140-1&2 F		57.86	87%	50.34	-7.52	51.8	152.2
5-164-2&3 F		19.61	100%	19.61	0.00	32.0	172.0
5-250-1&2 F		68.40	0%	0.00	-68.40	-59.8	263.8
DIESEL OIL SERVICE							
5-204-1&2 F	94.6	64.58	50%	47.30	-17.28	-4.0	208.0
5-201-1&3 F	2.44	0.00	50%	1.22	1.22	1.7	202.4
3-240-1&2 F	5.16	0.00	50%	2.58	2.58	-40.7	244.7
3-292-4&6 F	2.49	0.00	50%	1.25	1.25	-89.2	293.2
2-276-2 J	1.08	0.00	50%	0.54	0.54	-73.1	277.1
JP-5							
5-328-0 J		26.51	100%	26.51	0.00	-131.7	335.7
5-344-0 J		29.80	100%	29.80	0.00	-150.8	354.8
3-316-1 J		3.80	100%	3.80	0.00	-114.9	318.9
3-322-1 J		3.70	100%	3.70	0.00	-120.8	324.8
TOTAL LOADS:	891.53	841.38		740.49			

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
** SW BALLAST **		TANK CAP					
5-32-0 W		45	0%	0	0		44
5-116-0 W		59	0%	0	0		124
5-250-1&2 F		83	0%	0	0		263.8
5-328-1&2 W		24	0%	0	0		341
5-100-3&4 F		79	0%	0	0		111.7
5-140-1&2 W			0%				
5-64-0 F			0%				
		TONS BAL.:		0	0		
TOTAL LOADS, INCLUDING BALLAST:				740.5	-100.9		

SPREADSHEET FOR COMPUTING LONGITUDINAL WEIGHT DISTRIBUTION
FFG36-61
BASED ON THE LONG. STRENGTH DRAWINGS

DESIRED DISPLACEMENT 3987.7 ltons From FFG61 FINAL WT REPT (JULY 1989)

STATION		FRAME from	FRAME to	ORD. FROM DWG. WT/ft	WT/ft*dx	FULL LOAD WEIGHT, ltons	80% FUEL COND. WEIGHT, ltons
A	0	-28.3	0.0	0.38	10.8	28.7	28.7
0	1	0.0	20.4	0.78	15.9	42.4	42.4
1	2	20.4	40.8	1.48	30.2	80.5	80.5
2	3	40.8	61.2	1.96	40.0	106.6	106.6
3	4	61.2	81.6	3.76	76.7	204.6	204.6
4	5	81.6	102.0	4.30	87.7	233.9	233.9
5	6	102.0	122.4	5.20	106.1	282.9	260.7
6	7	122.4	142.8	5 34	108.9	290.5	290.5
7	8	142.8	163.2	3.62	73.8	196.9	189.4
8	9	163.2	183.6	3.52	71.8	191.5	194.5
9	10	183.6	204.0	4.44	90.6	241.5	242.8
10	11	204.0	224.4	4.70	95.9	255.7	238.4
11	12	224.4	244.8	4.52	92.2	245.9	248.5
12	13	244.8	265.2	4.30	87.7	233.9	165.5
13	14	265.2	285.6	5.56	113.4	302.5	306.6
14	15	285.6	306.0	4.70	95.9	255.7	259.4
15	16	306.0	326.4	3.30	67.3	179.5	179.5
16	17	326.4	346.8	3.34	68.1	181.7	181.7
17	18	346.8	367.2	2.28	46.5	124.0	124.0
18	19	367.2	387.6	2.94	60.0	159.9	159.9
19	20	387.6	408.0	2.44	49.8	132.7	132.7
20	B	408.0	420.0	0.50	6.0	16.0	16.0
		420					
			TOTALS:		1495.3	3987.7	3886.8

FFG61 LOADS AND LCG's ** FULL LOAD AND 60% FUEL CONDITION **

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
OFFICERS, CREW, & EFFECTS		24.39	100%	24.39	0.00	54.2	149.8
TORPEDOES IN TUBES		1.36	100%	1.36	0.00	-8.9	212.9
MISSILES		24.55	100%	24.55	0.00	130.0	74.0
76mm IN MOUNT & MAG.		11.29	100%	11.29	0.00	-36.0	240.0
SMALL ARMS		3.15	100%	3.15	0.00	143.0	61.0
CIWS IN MOUNT AND MAG.		4.93	100%	4.93	0.00	-107.0	311.0
TORPEDOES IN MAG.		4.08	100%	4.08	0.00	-23.0	227.0
SONOBOUYS		4.29	100%	4.29	0.00	-74.0	278.0
CAD (CARTRIDGE ACTV. DEV.)		0.75	100%	0.75	0.00	153.0	51.0
OTHER		0.75	100%	0.75	0.00	-45.0	249.0
LAMPS III HELOS		15.91	100%	15.91	0.00	-96.0	300.0
HELO SUPPORT		5.10	100%	5.10	0.00	-135.0	339.0
HELO SPARES/MAINT.		3.14	100%	3.14	0.00	-61.0	265.0
HELO OP. FLUIDS		1.17	100%	1.17	0.00	25.3	178.7
DRY, CHILL, & FREEZE PROV.		23.58	100%	23.58	0.00	13.0	191.0
SHIP'S STORE STRM		3.49	100%	3.49	0.00	4.0	200.0
SMALL STORES		0.31	100%	0.31	0.00	146.0	58.0
GENERAL STORES, FWD		10.52	100%	10.52	0.00	160.0	44.0
GEN STORES, AFT		8.21	100%	8.21	0.00	-155.0	359.0
** LIQUID LOADS **							
POTABLE WATER							
5-292-2&3 W		17.44	100%	17.44	0.00	-94.0	298.0
5-308-1&2 W		15.76	100%	15.76	0.00	-116.0	320.0
COLLECTING & HOLDING TANK							
4-170-0 W	2.96	0.00	100%	2.96	2.96	30.1	173.9
LUBE OIL STORAGE							
3-272-2 F		3.50	100%	3.50	0.00	-70.6	274.6
3-278-2 F		4.00	100%	4.00	0.00	-78.0	282.0
3-286-2 F		2.75	100%	2.75	0.00	-85.1	289.1
SSGD LUBE OIL							
4-208-2 F		0.95	100%	0.95	0.00	-6.3	210.3
3-236-1&2 F		2.10	100%	2.10	0.00	-34.3	238.3
3-292-8 F		0.92	100%	0.92	0.00	-89.1	293.1
LUBE OIL SETTLING							
3-278-1 F	3.58	0.00	100%	3.58	3.58	-77.9	281.9
3-286-1 F	2.42	0.00	100%	2.42	2.42	-84.7	288.7
DIESEL OIL STORAGE							
5-56-0 F		14.83	100%	14.83	0.00	143.9	60.1
5-64-0 F		42.05	100%	42.05	0.00	129.6	74.4
5-84-1&2 F		112.74	100%	112.74	0.00	111.8	92.2
5-100-3&4 F		65.40	0%	0.00	-65.40	92.3	111.7
5-116-1&2 F		133.72	43%	56.83	-76.89	75.6	128.4
5-140-1&2 F		57.86	87%	50.34	-7.52	51.8	152.2
5-164-2&3 F		19.61	100%	19.61	0.00	32.0	172.0
5-250-1&2 F		68.40	0%	0.00	-68.40	-59.8	263.8
DIESEL OIL SERVICE							
5-204-1&2 F	94.6	64.58	50%	47.30	-17.28	-4.0	208.0
5-201-1&3 F	2.44	0.00	50%	1.22	1.22	1.7	202.4
3-240-1&2 F	5.16	0.00	50%	2.58	2.58	-40.7	244.7
3-292-4&6 F	2.49	0.00	50%	1.25	1.25	-89.2	293.2
2-276-2 J	1.08	0.00	50%	0.54	0.54	-73.1	277.1
JP-5							
5-328-0 J		26.51	100%	26.51	0.00	-131.7	335.7
5-344-0 J		29.80	100%	29.80	0.00	-150.8	354.8
3-316-1 J		3.80	100%	3.80	0.00	-114.9	318.9
3-322-1 J		3.70	100%	3.70	0.00	-120.8	324.8
TOTAL LOADS:	891.53	841.38		620.43			

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
** SW BALLAST **		TANK CAP					
5-32-0 W		45	100%	45	45		44
5-116-0 W		59	100%	59	59		124
5-250-1&2 F		83	0%	0	0		263.8
5-328-1&2 W		24	0%	0	0		341
5-100-3&4 F		79	0%	0	0		111.7
5-140-1&2 W			0%				
5-64-0 F			0%				
		TONS BAL.:		104	104		
TOTAL LOADS, INCLUDING BALLAST:				724.4	-116.9		

SPREADSHEET FOR COMPUTING LONGITUDINAL WEIGHT DISTRIBUTION
FFG36-61
BASED ON THE LONG. STRENGTH DRAWINGS

DESIRED DISPLACEMENT 3987.7 ltons From FFG61 FINAL WT REPT (JULY 1989)

STATION		FRAME from	to	ORD. FROM DWG. WT/ft	WT/ft*dx	FULL LOAD WEIGHT, ltons	60% FUEL WEIGHT, ltons
A	0	-28.3	0.0	0.38	10.8	28.7	28.7
0	1	0.0	20.4	0.78	15.9	42.4	42.4
1	2	20.4	40.8	1.48	30.2	80.5	80.5
2	3	40.8	61.2	1.96	40.0	106.6	151.6
3	4	61.2	81.6	3.76	76.7	204.6	204.6
4	5	81.6	102.0	4.30	87.7	233.9	233.9
5	6	102.0	122.4	5.20	106.1	282.9	217.5
6	7	122.4	142.8	5.34	108.9	290.5	272.6
7	8	142.8	163.2	3.62	73.8	196.9	189.4
8	9	163.2	183.6	3.52	71.8	191.5	194.5
9	10	183.6	204.0	4.44	90.6	241.5	242.8
10	11	204.0	224.4	4.70	95.9	255.7	238.4
11	12	224.4	244.8	4.52	92.2	245.9	248.5
12	13	244.8	265.2	4.30	87.7	233.9	165.5
13	14	265.2	285.6	5.56	113.4	302.5	306.6
14	15	285.6	306.0	4.70	95.9	255.7	259.4
15	16	306.0	326.4	3.30	67.3	179.5	179.5
16	17	326.4	346.8	3.34	68.1	181.7	181.7
17	18	346.8	367.2	2.28	46.5	124.0	124.0
18	19	367.2	387.6	2.94	60.0	159.9	159.9
19	20	387.6	408.0	2.44	49.8	132.7	132.7
20	B	408.0	420.0	0.50	6.0	16.0	16.0
		420					
			TOTALS:		1495.3	3987.7	3870.8

FFG61 LOADS AND LCG's ** FULL LOAD AND MINIMUM OPERATING CONDITION **

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
OFFICERS, CREW, & EFFECTS		24.39	100%	24.39	0.00	54.2	149.8
TORPEDOES IN TUBES		1.36	100%	1.36	0.00	-8.9	212.9
MISSILES		24.55	100%	24.55	0.00	130.0	74.0
76mm IN MOUNT & MAG.		11.29	33%	3.76	-7.53	-36.0	240.0
SMALL ARMS		3.15	33%	1.05	-2.10	143.0	61.0
CIWS IN MOUNT AND MAG.		4.93	33%	1.64	-3.29	-107.0	311.0
TORPEDOES IN MAG.		4.08	100%	4.08	0.00	-23.0	227.0
SONOBOUYS		4.29	33%	1.43	-2.86	-74.0	278.0
CAD (CARTRIDGE ACTV. DEV.)		0.75	33%	0.25	-0.50	153.0	51.0
OTHER HELO ORD.		0.75	33%	0.25	-0.50	-45.0	249.0
LAMPS III HELOS		15.91	100%	15.91	0.00	-96.0	300.0
HELO SUPPORT		5.10	100%	5.10	0.00	-135.0	339.0
HELO SPARES/MAINT.		3.14	100%	3.14	0.00	-61.0	265.0
HELO OP. FLUIDS		1.17	100%	1.17	0.00	25.3	178.7
DRY, CHILL, & FREEZE PROV.		23.58	33%	7.86	-15.72	13.0	191.0
SHIP'S STORE STRM		3.49	33%	1.16	-2.33	4.0	200.0
SMALL STORES		0.31	33%	0.10	-0.21	146.0	58.0
GENERAL STORES, FWD		10.52	33%	3.51	-7.01	160.0	44.0
GEN STORES, AFT		8.21	33%	2.74	-5.47	-155.0	359.0
** LIQUID LOADS **							
POTABLE WATER							
5-292-2&3 W		17.44	67%	11.63	-5.81	-94.0	298.0
5-308-1&2 W		15.76	67%	10.51	-5.25	-116.0	320.0
COLLECTING & HOLDING TANK							
4-170-0 W	2.96	0.00	100%	2.96	2.96	30.1	173.9
LUBE OIL STORAGE							
3-272-2 F		3.50	33%	1.17	-2.33	-70.6	274.6
3-278-2 F		4.00	33%	1.33	-2.67	-78.0	282.0
3-286-2 F		2.75	33%	0.92	-1.83	-85.1	289.1
SSGD LUBE OIL							
4-208-2 F		0.95	33%	0.32	-0.63	-6.3	210.3
3-236-1&2 F		2.10	33%	0.70	-1.40	-34.3	238.3
3-292-8 F		0.92	33%	0.31	-0.61	-89.1	293.1
LUBE OIL SETTLING							
3-278-1 F	3.58	0.00	33%	1.19	1.19	-77.9	281.9
3-286-1 F	2.42	0.00	33%	0.81	0.81	-84.7	288.7
DIESEL OIL STORAGE							
5-56-0 F		14.83	100%	14.83	0.00	143.9	60.1
5-64-0 F		42.05	100%	42.05	0.00	129.6	74.4
5-84-1&2 F		112.74	100%	112.74	0.00	111.8	92.2
5-100-3&4 F		65.40	0%	0.00	-65.40	92.3	111.7
5-116-1&2 F		133.72	0%	0.00	-133.72	75.6	128.4
5-140-1&2 F		57.86	0%	0.00	-57.86	51.8	152.2
5-164-2&3 F		19.61	0%	0.00	-19.61	32.0	172.0
5-250-1&2 F		68.40	0%	0.00	-68.40	-59.8	263.8
DIESEL OIL SERVICE							
5-204-1&2 F	94.6	64.58	50%	47.30	-17.28	-4.0	208.0
5-201-1&3 F	2.44	0.00	50%	1.22	1.22	1.7	202.4
3-240-1&2 F	5.16	0.00	50%	2.58	2.58	-40.7	244.7
3-292-4&6 F	2.49	0.00	50%	1.25	1.25	-89.2	293.2
2-276-2 J	1.08	0.00	50%	0.54	0.54	-73.1	277.1
JP-5							
5-328-0 J		26.51	33%	8.84	-17.67	-131.7	335.7
5-344-0 J		29.80	33%	9.93	-19.87	-150.8	354.8
3-316-1 J		3.80	33%	1.27	-2.53	-114.9	318.9
3-322-1 J		3.70	33%	1.23	-2.47	-120.8	324.8
TOTAL LOADS:	891.53	841.38		379.06			

LOAD ITEM	WT CAP LOAD ltons	WT FULL LOAD ltons	% OF FULL LOAD %	WT AT GIVEN % ltons	DIFF FROM WT-FL ltons	LCG FROM MID-SHIP LCG-MS ft.	LCG FROM FP LCG-FP ft.
** SW BALLAST **		TANK CAP					
5-32-0 W		45	100%	45	45		44
5-116-0 W		59	100%	59	59		124
5-250-1&2 F		83	100%	83	83		263.8
5-328-1&2 W		24	100%	24	24		341
5-100-3&4 F		79	100%	79	79		111.7
5-140-1&2 W			0%				
5-64-0 F			0%				
		TONS BAL.:		290	290		
TOTAL LOADS, INCLUDING BALLAST:				669.1	-172.3		

SPREADSHEET FOR COMPUTING LONGITUDINAL WEIGHT DISTRIBUTION
FFG36-61
BASED ON THE LONG. STRENGTH DRAWINGS

DESIRED DISPLACEMENT 3987.7 ltons From FFG61 FINAL WT REPT (JULY 1989)

STATION		FRAME from	FRAME to	ORD. FROM DWG. WT/ft	ORD. FROM DWG. WT/ft*dx	FULL LOAD WEIGHT, ltons	MIN. OPS. WEIGHT, ltons
A	0	-28.3	0.0	0.38	10.8	28.7	28.7
0	1	0.0	20.4	0.78	15.9	42.4	42.4
1	2	20.4	40.8	1.48	30.2	80.5	80.5
2	3	40.8	61.2	1.96	40.0	106.6	141.8
3	4	61.2	81.6	3.76	76.7	204.6	204.6
4	5	81.6	102.0	4.30	87.7	233.9	233.9
5	6	102.0	122.4	5.20	106.1	282.9	296.5
6	7	122.4	142.8	5.34	108.9	290.5	215.8
7	8	142.8	163.2	3.62	73.8	196.9	139.1
8	9	163.2	183.6	3.52	71.8	191.5	174.8
9	10	183.6	204.0	4.44	90.6	241.5	224.7
10	11	204.0	224.4	4.70	95.9	255.7	237.8
11	12	224.4	244.8	4.52	92.2	245.9	239.6
12	13	244.8	265.2	4.30	87.7	233.9	248.0
13	14	265.2	285.6	5.56	113.4	302.5	296.3
14	15	285.6	306.0	4.70	95.9	255.7	249.5
15	16	306.0	326.4	3.30	67.3	179.5	166.0
16	17	326.4	346.8	3.34	68.1	181.7	188.0
17	18	346.8	367.2	2.28	46.5	124.0	98.7
18	19	367.2	387.6	2.94	60.0	159.9	159.9
19	20	387.6	408.0	2.44	49.8	132.7	132.7
20	B	408.0	420.0	0.50	6.0	16.0	16.0
		420					
			TOTALS:		1495.3	3987.7	3815.4

Appendix B: SHCP Graphic and Numerical Output

```
FULL LOAD, SEASTATE 0

                        SSSS     HH       HH     CCCC      PPPPPPP
                       SSSSSS    HH       HH    CCCCCC     PPPPPPPP
                     SS    SS   HH       HH   CC     CC   PP     PP
                   SS      SS  HH       HH  CC       CC  PP       PP
                   SS         HH       HH  CC       CC  PP      PP
                   SSSS      HHHHHHHHHH  CC            PPPPPPPP
                    SSSS    HHHHHHHHHH  CC            PPPPPPP
               SS      SS   HH       HH  CC       CC  PP
              SS       SS  HH       HH  CC       CC  PP
              SS    SS   HH       HH  CC      CC   PP
              SSSSSS    HH       HH   CCCCCC     PP
               SSSS     HH       HH    CCCC      PP


                     SHIP HULL CHARACTERISTICS PROGRAM


0DESIGN DISPLACEMENT                3987.720 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT   (+ ABOVE BL)          15.935 FT |
 DESIGN LCG     (+ FWD MID)           -6.110 FT | DESIGN LCB  (+ F MID)       -6.110 FT
 DESIGN VCG     (+ ABOVE BL)          0.     FT | DESIGN VCB  (+ ABL)          9.971 FT
 DESIGN TCG     (+ STBD)              0.     FT | DESIGN TCB  (+ STBD)         0.    FT
 DESIGN TRIM    (+ BY STERN)           0.993 FT | DESIGN LIST (+ STBD)         0.    DEG
0LENGTH OVERALL                      447.780 FEET
 LENGTH BETWEEN PERPENDICULARS       408.000 FEET
 LENGTH ON DESIGN WATERLINE          409.645 FEET
0STATION OF MAX AREA  (AT DWL)       211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA          45.407 FEET
 SECTION AREA COEFFICIENT            0.7667
 PRISMATIC COEFFICIENT               0.6160
 BLOCK COEFFICIENT                   0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =         20 and LBP =         20
0                 Approximate Bounding C'be Values:
+       _____________________________________________________
        Forward X location            -27.948 Ft  (+ Aft FP)
        After   X lccation            419.832 Ft  (+ Aft FP)
        Maximum Y value on Station     46.938 Ft
        Minimum Z value on Station     0.     Ft  (+ Abv BL)
        Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0                 Work List and Requested Options:
+______________________________________________________________________
     1    3 Longitudinal Strength

   KK      3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT   3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF    F Plots will be SHCP NEUT.AL PLOTFILE format
   KKAP    3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP  0 NO Appendage PLOTS
   IPLCON  0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV  0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT   0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-            FFG61 FULL LOAD              SERIAL NUMBER-     1  DATE- 6-Aug-90
0                             LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS   0.     FEET (+ FWD)
 WAVE LENGTH/LBP             1.000
 WAVE HEIGHT=1.1*SQRT(LBP)   22.22 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =         20 and LBP =         20

0  WEIGHT    WEIGHT    LCG OF WEIGHT      -- SECTION MODULUS --
```

STATION (FROM FP)	(TONS)	FROM AMIDSHIPS (FT,+FWD)	(INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	106.63	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	282.89	91.80		
142.80	290.51	71.40		
163.20	196.93	51.00		
183.60	191.49	30.60		
204.00	241.54	10.20		
224.40	255.69	-10.20		
244.80	245.90	-30.60		
265.20	233.93	-51.00		
285.60	302.47	-71.40		
306.00	255.69	-91.80		
326.40	179.53	-112.20		
346.80	181.70	-132.60		
367.20	124.04	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

1SHIP- FFG61 FULL LOAD SERIAL NUMBER- 1 DATE- 6-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	15.396	0.	195.718	15.918	548.575
-23.914	15.406	0.	200.200	15.928	552.081
-19.432	15.416	0.	204.682	15.939	554.701
-14.949	15.427	0.	209.165	15.949	555.358
-10.467	15.437	0.	213.647	15.960	555.340
-5.985	15.448	0.	218.129	15.970	554.649
-1.503	15.458	0.	222.612	15.981	553.283
2.980	15.469	7.377	227.094	15.991	551.243
7.462	15.479	18.967	231.576	16.002	548.529
11.944	15.489	31.693	236.058	16.012	545.141
16.427	15.500	45.554	240.541	16.022	541.078
20.909	15.510	60.551	245.023	16.033	536.380
25.391	15.521	76.683	249.505	16.043	531.531
29.873	15.531	93.951	253.988	16.054	525.622
34.356	15.542	112.353	258.470	16.064	518.654
38.838	15.552	131.892	262.952	16.075	510.626
43.320	15.563	150.826	267.434	16.085	501.539
47.803	15.573	168.393	271.917	16.096	491.392
52.285	15.584	185.591	276.399	16.106	480.185
56.767	15.594	202.451	280.881	16.117	467.919
61.249	15.604	218.962	285.364	16.127	454.593
65.732	15.615	235.125	289.846	16.137	440.498
70.214	15.625	250.939	294.328	16.148	426.141
74.696	15.636	266.405	298.810	16.158	411.526
79.179	15.646	281.522	303.293	16.169	396.655
83.661	15.657	295.832	307.775	16.179	381.526
88.143	15.667	309.383	312.257	16.190	366.140
92.625	15.678	322.759	316.740	16.200	350.497
97.108	15.688	335.960	321.222	16.211	334.596
101.590	15.698	348.986	325.704	16.221	318.439

106.072	15.709	361.838	330.186	16.231	302.185
110.555	15.719	374.516	334.669	16.242	286.233
115.037	15.730	387.018	339.151	16.252	270.596
119.519	15.740	399.346	343.633	16.263	255.276
124.001	15.751	411.480	348.116	16.273	240.271
128.484	15.761	423.297	352.598	16.284	225.582
132.966	15.772	434.782	357.080	16.294	211.209
137.448	15.782	445.936	361.562	16.305	197.152
141.931	15.793	456.759	366.045	16.315	183.411
146.413	15.803	467.250	370.527	16.326	170.491
150.895	15.813	477.409	375.009	16.336	157.195
155.377	15.824	487.236	379.491	16.346	143.216
159.860	15.834	496.733	383.974	16.357	128.555
164.342	15.845	505.755	388.456	16.367	113.212
168.824	15.855	513.831	392.938	16.378	97.186
173.306	15.866	521.253	397.421	16.388	80.479
177.789	15.876	528.023	401.903	16.399	63.089
182.271	15.887	534.140	406.385	16.409	45.017
186.753	15.897	539.604	410.867	16.420	0.
191.236	15.907	544.416	415.350	16.430	0.
195.718	15.918	548.575	419.831	16.440	0.

1SHIP- FFG61 FULL LOAD SERIAL NUMBER- 1 DATE- 6-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION WEIGHT BUOYANCY SHEAR BENDING MOM WEIGHT BUOYANCY SHEAR MOMENT STRESS (TONS/IN**2)

FT FM FP	TONS	TONS	TONS	FOOT-TONS	ORD	ORD	ORD	ORD
DECK	KEEL							
-29.00			0.	0.			0.	0.
	28.68	0.00			0.30	0.00		
0.			28.68	405.8			0.216	0.050
	42.43	16.08			0.64	0.24		
20.40			55.03	1317.6			0.414	0.162
	80.51	57.02			1.21	0.86		
40.80			78.52	2761.1			0.591	0.339
	106.63	105.14			1.60	1.58		
61.20			80.00	4455.2			0.602	0.548
	204.55	148.49			3.08	2.23		
81.60			136.06	6729.2			1.024	0.827
	233.93	186.61			3.52	2.81		
102.00			183.39	10047.6			1.380	1.235
	282.89	220.89			4.26	3.32		
122.40			245.39	14477.6			1.846	1.780
	290.51	252.71			4.37	3.80		
142.80			283.19	19920.2			2.130	2.449
	196.93	280.81			2.96	4.23		
163.20			199.31	24886.1			1.499	3.059
	191.49	303.57			2.88	4.57		
183.60			87.22	27840.7			0.656	3.422
	241.54	318.42			3.63	4.79		
204.00			10.34	28854.4			0.078	3.547
	255.69	323.32			3.85	4.86		
224.40			-57.28	28373.6			-0.431	3.488
	245.90	318.09			3.70	4.79		
244.80			-129.47	26453.0			-0.974	3.252
	233.93	304.97			3.52	4.59		
265.20			-200.50	23057.2			-1.508	2.834
	302.47	280.85			4.55	4.23		
285.60			-178.89	19135.5			-1.346	2.352
	255.69	245.47			3.85	3.69		
306.00			-168.67	15524.7			-1.269	1.908
	179.53	205.27			2.70	3.09		

326.40			-194.40	11750.3			-1.463	1.444
	181.70	163.04			2.73	2.45		
346.80			-175.75	7904.4			-1.322	0.972
	124.04	123.41			1.87	1.86		
367.20			-175.12	4261.3			-1.317	0.524
	159.94	86.98			2.41	1.31		
387.60			-102.16	1369.8			-0.769	0.168
	132.74	45.72			2.00	0.69		
408.00			-15.14	96.1			-0.114	0.012
	16.00	0.86			0.41	0.02		
420.00			0.	0.6			0.	0.000

MOMENT AT ZERO SHEAR= 28870.5 FOOT-TONS LOCATED 207.120 FT FROM FP

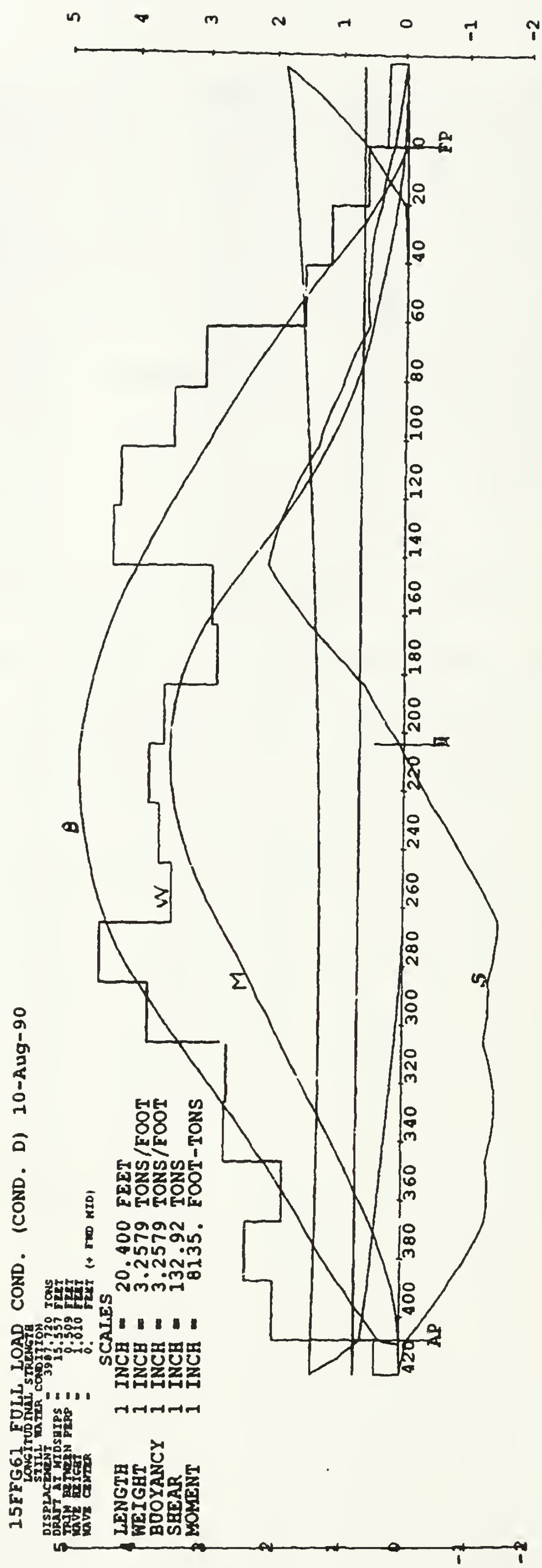

Figure B-1: SHCP Results, Full Load, Seastate 0

80% FUEL CONDITION, SEASTATE 0

```
                    SSSS      HH        HH      CCCC      PPPPPPP
                   SSSSSS     HH        HH     CCCCCC     PPPPPPPP
                 SS     SS    HH        HH   CC     CC    PP     PP
               SS       SS   HH        HH   CC      CC   PP      PP
               SS           HH        HH   CC      CC   PP      PP
               SSSS        HHHHHHHHHH   CC             PPPPPPPP
                SSSS      HHHHHHHHHH   CC             PPPPPPP
           SS      SS    HH        HH   CC      CC   PP
          SS      SS    HH        HH   CC      CC   PP
          SS     SS    HH        HH   CC     CC    PP
          SSSSSS     HH        HH    CCCCCC      PP
           SSSS      HH        HH     CCCC       PP
```

SHIP HULL CHARACTERISTICS PROGRAM

```
1SHIP-          FFG61 80% FUEL COND.          SERIAL NUMBER-    7  DATE-17-Aug-90
          .
          .
          .
0DESIGN DISPLACEMENT                 3987.720 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT    (+ ABOVE BL)          15.935 FT |
 DESIGN LCG      (+ FWD MID)           -6.110 FT | DESIGN LCB  (+ F MID)       -6.110 FT
 DESIGN VCG      (+ ABOVE BL)           0.    FT | DESIGN VCB  (+ ABL)          9.971 FT
 DESIGN TCG      (+ STBD)               0.    FT | DESIGN TCB  (+ STBD)         0.    FT
 DESIGN TRIM     (+ BY STERN)           0.993 FT | DESIGN LIST (+ STBD)         0.    DEG
0LENGTH OVERALL                       447.780 FEET
 LENGTH BETWEEN PERPENDICULARS        408.000 FEET
 LENGTH ON DESIGN WATERLINE           409.645 FEET
0STATION OF MAX AREA  (AT DWL)        211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA           45.407 FEET
 SECTION AREA COEFFICIENT              0.7667
 PRISMATIC COEFFICIENT                 0.6160
 BLOCK COEFFICIENT                     0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =        20 and LBP =          20
0               Approximate Bounding Cube Values:
+        ________________________________________________________
         Forward X location             -27.948 Ft  (+ Aft FP)
         After   X location             419.832 Ft  (+ Aft FP)
         Maximum Y value on Station      46.938 Ft
         Minimum Z value on Station       0.    Ft  (+ Abv BL)
         Maximum Z value on Station      41.893 Ft  (+ Abv BL)
0               Work List and Requested Options:
+___________________________________________________________________
    1    3 Longitudinal Strength

   KK     3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT  3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF   F Plots will be SHCP NEUTRAL PLOTFILE format
   KKAP   3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP 0 NO Appendage PLOTS
   IPLCON 0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV 0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT  0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-          FFG61 80% FUEL COND.          SERIAL NUMBER-    7  DATE-17-Aug-90
0                       LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS    0.    FEET  (+ FWD)
 WAVE LENGTH/LBP              1.000
 WAVE HEIGHT=1.1*SQRT(LBP)    22.22 FEET
```

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
Maximum Iteration for Volume = 20 and LBP = 20

0 WEIGHT STATION (FROM FP)	WEIGHT (TONS)	LCG OF WEIGHT FROM AMIDSHIPS (FT,+FWD)	-- SECTION MODULUS -- (INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	106.63	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	260.65	91.80		
142.80	290.51	71.40		
163.20	189.41	51.00		
183.60	194.45	30.60		
204.00	242.76	10.20		
224.40	238.41	-10.20		
244.80	248.48	-30.60		
265.20	165.53	-51.00		
285.60	306.59	-71.40		
306.00	259.35	-91.80		
326.40	179.53	-112.20		
346.80	181.70	-132.60		
367.20	124.04	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

1SHIP- FFG61 80% FUEL COND. SERIAL NUMBER- 7 DATE-17-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	15.015	0.	195.718	15.646	536.424
-23.914	15.027	0.	200.200	15.659	539.959
-19.432	15.039	0.	204.682	15.672	542.622
-14.949	15.052	0.	209.165	15.684	543.344
-10.467	15.065	0.	213.647	15.697	543.399
-5.985	15.077	0.	218.129	15.710	542.787
-1.503	15.090	0.	222.612	15.722	541.508
2.980	15.103	6.863	227.094	15.735	539.562
7.462	15.115	17.935	231.576	15.747	536.949
11.944	15.128	30.150	236.058	15.760	533.669
16.427	15.141	43.507	240.541	15.773	529.721
20.909	15.153	58.007	245.023	15.785	525.145
25.391	15.166	73.650	249.505	15.798	520.428
29.873	15.179	90.435	253.988	15.811	514.656
34.356	15.191	108.364	258.470	15.823	507.828
38.838	15.204	127.434	262.952	15.836	499.945
43.320	15.216	145.908	267.434	15.849	491.006
47.803	15.229	163.014	271.917	15.861	481.012
52.285	15.242	179.786	276.399	15.874	469.962
56.767	15.254	196.221	280.881	15.887	457.857
61.249	15.267	212.322	285.364	15.899	444.697
65.732	15.280	228.087	289.846	15.912	430.774
70.214	15.292	243.516	294.328	15.924	416.593
74.696	15.305	258.610	298.810	15.937	402.159
79.179	15.318	273.369	303.293	15.950	387.472
83.661	15.330	287.336	307.775	15.962	372.532
88.143	15.343	300.560	312.257	15.975	357.340

92.625	15.356	313.623	316.740	15.988	341.894
97.108	15.368	326.526	321.222	16.000	326.196
101.590	15.381	339.269	325.704	16.013	310.245
106.072	15.393	351.851	330.186	16.026	294.200
110.555	15.406	364.272	334.669	16.038	278.454
115.037	15.419	376.533	339.151	16.051	263.022
119.519	15.431	388.633	343.633	16.064	247.905
124.001	15.444	400.560	348.116	16.076	233.102
128.484	15.457	412.195	352.598	16.089	218.613
132.966	15.469	423.513	357.080	16.101	204.438
137.448	15.482	434.515	361.562	16.114	190.578
141.931	15.495	445.199	366.045	16.127	177.031
146.413	15.507	455.566	370.527	16.139	164.292
150.895	15.520	465.616	375.009	16.152	151.182
155.377	15.533	475.348	379.491	16.165	137.400
159.860	15.545	484.764	383.974	16.177	122.947
164.342	15.558	493.721	388.456	16.190	107.822
168.824	15.570	501.746	392.938	16.203	92.027
173.306	15.583	509.129	397.421	16.215	75.561
177.789	15.596	515.870	401.903	16.228	58.424
182.271	15.608	521.971	406.385	16.240	40.616
186.753	15.621	527.430	410.867	16.253	0.
191.236	15.634	532.247	415.350	16.266	0.
195.718	15.646	536.424	419.831	16.278	0.

1SHIP- FFG61 80% FUEL COND. SERIAL NUMBER- 7 DATE-17-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DISPLACEMENT 3886.82 TONS SW LCG -6.002 FT FROM AMIDSHIPS (+ FWD)

0LOCATION WEIGHT BUOYANCY SHEAR BENDING MOM WEIGHT BUOYANCY SHEAR MOMENT
STRESS (TONS/IN**2)
FT FM FP TONS TONS TONS FOOT-TONS ORD ORD ORD ORD
DECK KEEL

0LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-29.00			0.	0.			0.	0.
	28.68	0.00			0.31	0.00		
0.			28.68	405.8			0.221	0.051
	42.43	15.30			0.65	0.24		
20.40			55.81	1323.3			0.431	0.167
	80.51	54.93			1.24	0.85		
40.80			81.39	2801.8			0.628	0.353
	106.63	101.84			1.65	1.57		
61.20			86.18	4586.3			0.665	0.578
	204.55	144.11			3.16	2.22		
81.60			146.62	7029.2			1.132	0.887
	233.93	181.32			3.61	2.80		
102.00			199.22	10615.5			1.538	1.339
	260.65	214.87			4.02	3.32		
122.40			245.00	15202.0			1.891	1.917
	290.51	246.16			4.48	3.80		
142.80			289 35	20702.9			2.233	2.611
	189.41	273.91			2.92	4.23		
163.20			204.85	25787.7			1.581	3.252
	194.45	296.51			3.00	4.58		
183.60			102.79	28957.4			0.793	3.652
	242.76	311.34			3.75	4.81		
204.00			34.21	30373.3			0.264	3.831
	238.41	316.37			3.68	4.88		
224.40			-43.75	30274.4			-0.338	3.818
	248.48	311.38			3.84	4.81		
244.80			-106.65	28725.1			-0.823	3.623
	165.53	298.60			2.56	4.61		
265.20			-239.71	25162.7			-1.850	3.173
	306.59	274.88			4.73	4.24		
285.60			-208.00	20544.8			-1.605	2.591

	259.35	239.94			4.00	3.70		
306.00			-188.59	16434.6			-1.456	2.073
	179.53	200.24			2.77	3.09		
326.40			-209.30	12306.2			-1.615	1.552
	181.70	158.56			2.80	2.45		
346.80			-186.16	8202.7			-1.437	1.035
	124.04	119.46			1.91	1.84		
367.20			-181.58	4388.6			-1.402	0.553
	159.94	83.54			2.47	1.29		
387.60			-105.19	1401.3			-0.812	0.177
	132.74	42.87			2.05	0.66		
408.00			-15.32	96.0			-0.118	0.012
	16.00	0.68			0.42	0.02		
420.00			-0.00	0.4			-0.000	0.000

MOMENT AT ZERO SHEAR= 30526.2 FOOT-TONS LOCATED 212.926 FT FROM FP

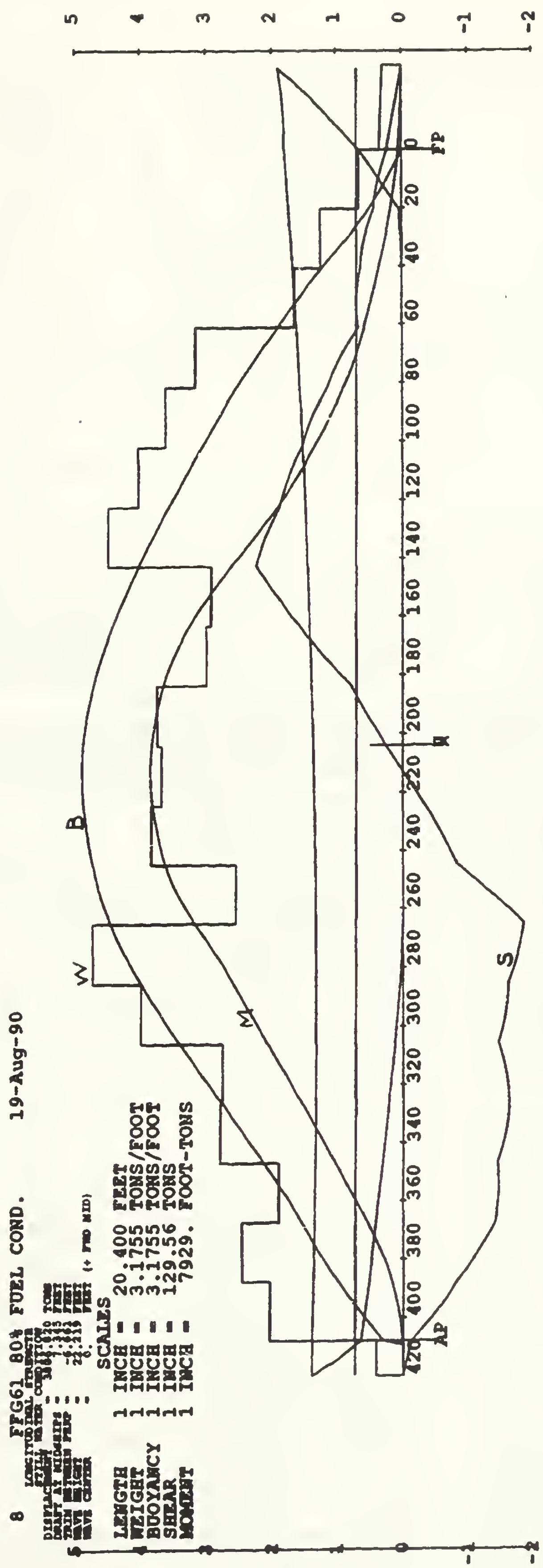

Figure B-2: SHCP Results, 80% Fuel Condition, Seastate 0

60% FUEL CONDITION, SEASTATE 0

```
                          SSSS     HH       HH      CCCC      PPPPPPP
                         SSSSSS    HH       HH     CCCCCC     PPPPPPPP
                       SS    SS   HH       HH   CC    CC   PP      PP
                     SS      SS  HH       HH  CC      CC  PP      PP
                     SS         HH       HH  CC      CC  PP      PP
                     SSSS      HHHHHHHHHH  CC          PPPPPPPP
                      SSSS    HHHHHHHHHH  CC          PPPPPPP
                 SS     SS   HH       HH  CC      CC  PP
                SS      SS  HH       HH  CC      CC  PP
                SS    SS   HH       HH  CC    CC   PP
                SSSSSS    HH       HH   CCCCCC    PP
                 SSSS     HH       HH    CCCC     PP


1SHIP-         FFG61    60% FUEL COND.          SERIAL NUMBER-     1  DATE-17-Aug-90
          .
          .
          .
0DESIGN DISPLACEMENT              3987.720 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT   (+ ABOVE BL)        15.935 FT |
 DESIGN LCG     (+ FWD MID)         -6.110 FT | DESIGN LCB  (+ F MID)       -6.110 FT
 DESIGN VCG     (+ ABOVE BL)        0.     FT | DESIGN VCB  (+ ABL)          9.971 FT
 DESIGN TCG     (+ STBD)            0.     FT | DESIGN TCB  (+ STBD)        0.     FT
 DESIGN TRIM    (+ BY STERN)         0.993 FT | DESIGN LIST (+ STBD)        0.      DEG
0LENGTH OVERALL                    447.780 FEET
 LENGTH BETWEEN PERPENDICULARS     408.000 FEET
 LENGTH ON DESIGN WATERLINE        409.645 FEET
0STATION OF MAX AREA  (AT DWL)     211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA        45.407 FEET
 SECTION AREA COEFFICIENT           0.7667
 PRISMATIC COEFFICIENT              0.6160
 BLOCK COEFFICIENT                  0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20
0                Approximate Bounding Cube Values:
+        ___________________________ ___________________________
          Forward X location            -27.948 Ft  (+ Aft FP)
          After   X location            419.832 Ft  (+ Aft FP)
          Maximum Y value on Station     46.938 Ft
          Minimum Z value on Station     0.      Ft  (+ Abv BL)
          Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0                Work List and Requested Options:
+_______________________________________________________________________
     1     3 Longitudinal Strength

   KK      3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT   3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF    F Plots will be SHCP NEUTR^L PLOTFILE format
   KKAP    3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP  0 NO Appendage PLOTS
   IPLCON  0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV  0 Do not sa^e HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT   0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-         FFG61    60% FUEL COND.          SERIAL NUMBER-     1  DATE-17-Aug-90
0                        LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS    0.     FEET (+ FWD)
 WAVE LENGTH/LBP             1.000
 WAVE HEIGHT=1.1*SQRT(LBP)   22.22 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20
          .
```

0 WEIGHT STATION (FROM FP)	WEIGHT (TONS)	LCG OF WEIGHT FROM AMIDSHIPS (FT,+FWD)	— SECTION MODULUS — (INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	151.63	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	217.49	91.80		
142.80	272.62	71.40		
163.20	189.41	51.00		
183.60	194.45	30.60		
204.00	242.76	10.20		
224.40	238.41	-10.20		
244.80	248.48	-30.60		
265.20	165.53	-51.00		
285.60	306.59	-71.40		
306.00	259.35	-91.80		
326.40	179.53	-112.20		
346.80	181.70	-132.60		
367.20	124.04	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

MOMENT AT ZERO SHEAR= 87372.9 FOOT-TONS LOCATED 209.914 FT FROM FP

1SHIP- FFG61 60% FUEL COND. SERIAL NUMBER- 1 DATE-17-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	15.058	0.	195.718	15.616	535.085
-23.914	15.068	0.	200.200	15.628	538.546
-19.432	15.079	0.	204.682	15.639	541.136
-14.949	15.090	0.	209.165	15.650	541.788
-10.467	15.102	0.	213.647	15.661	541.774
-5.985	15.113	0.	218.129	15.672	541.094
-1.503	15.124	0.	222.612	15.683	539.747
2.980	15.135	6.906	227.094	15.695	537.735
7.462	15.146	18.021	231.576	15.706	535.056
11.944	15.158	30.274	236.058	15.717	531.711
16.427	15.169	43.665	240.541	15.728	527.700
20.909	15.180	58.195	245.023	15.739	523.060
25.391	15.191	73.863	249.505	15.751	518.284
29.873	15.202	90.670	253.988	15.762	512.454
34.356	15.213	108.616	258.470	15.773	505.570
38.838	15.225	127.700	262.952	15.784	497.632
43.320	15.236	146.182	267.434	15.795	488.641
47.803	15.247	163.292	271.917	15.807	478.595
52.285	15.258	180.064	276.399	15.818	467.496
56.767	15.269	196.496	280.881	15.829	455.344
61.249	15.281	212.588	285.364	15.840	442.137
65.732	15.292	228.341	289.846	15.851	428.171
70.214	15.303	243.754	294.328	15.863	413.950
74.696	15.314	258.827	298.810	15.874	399.480
79.179	15.325	273.562	303.293	15.885	384.760
83.661	15.337	287.500	307.775	15.896	369.790
88.143	15.348	300.692	312.257	15.907	354.571
92.625	15.359	313.720	316.740	15.918	339.102
97.108	15.370	326.584	321.222	15.930	323.383

101.590	15.381	339.285	325.704	15.941	307.415
106.072	15.393	351.822	330.186	15.952	291.356
110.555	15.404	364.195	334.669	15.963	275.599
115.037	15.415	376.405	339.151	15.974	260.159
119.519	15.426	388.451	343.633	15.986	245.035
124.001	15.437	400.320	348.116	15.997	230.227
128.484	15.448	411.897	352.598	16.008	215.735
132.966	15.460	423.154	357.080	16.019	201.560
137.448	15.471	434.093	361.562	16.030	187.702
141.931	15.482	444.713	366.045	16.042	174.159
146.413	15.493	455.015	370.527	16.053	161.420
150.895	15.504	464.997	375.009	16.064	148.314
155.377	15.516	474.661	379.491	16.075	134.547
159.860	15.527	484.007	383.974	16.086	120.120
164.342	15.538	492.892	388.456	16.097	105.032
168.824	15.549	500.844	392.938	16.109	89.283
173.306	15.560	508.155	397.421	16.120	72.874
177.789	15.572	514.824	401.903	16.131	55.803
182.271	15.583	520.852	406.385	16.142	38.072
186.753	15.594	526.237	410.867	16.153	0.
191.236	15.605	530.982	415.350	16.165	0.
195.718	15.616	535.085	419.831	16.176	0.

1SHIP- FFG61 60% FUEL COND. SERIAL NUMBER- 1 DATE-17-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DISPLACEMENT 3870.77 TONS SW LCG -5.602 FT FROM AMIDSHIPS (+ FWD)

OLOCATION	WEIGHT	BUOYANCY	SHEAR	BENDING MOM	WEIGHT	BUOYANCY	SHEAR	MOMENT'
STRESS (TONS/IN**2)								
FT FM FP	TONS	TONS	TONS	FOOT-TONS	ORD	ORD	ORD	ORD
DECK	KEEL							
-29.00			0.	0.			0.	0.
	28.68	0.00			0.31	0.00		
0.			28.68	405.8			0.222	0.051
	42.43	15.36			0.66	0.24		
20.40			55.75	1322.8			0.432	0.168
	80.51	55.07			1.25	0.85		
40.80			81.19	2798.8			0.629	0.354
	151.63	102.00			2.35	1.58		
61.20			130.82	5036.6			1.014	0.638
	204.55	144.25			3.17	2.24		
81.60			191.12	8388.8			1.481	1.062
	233.93	181.38			3.63	2.81		
102.00			243.67	12882.2			1.889	1.631
	217.49	214.82			3.37	3.33		
122.40			246.35	17935.6			1.909	2.271
	272.62	245.95			4.23	3.81		
142.80			273.02	23283.3			2.116	2.949
	189.41	273.53			2.94	4.24		
163.20			188.89	28038.4			1.464	3.551
	194.45	295.94			3.01	4.59		
183.60			87.40	30888.1			0.677	3.912
	242.76	310.58			3.76	4.81		
204.00			19.58	31997.5			0.152	4.052
	238.41	315.41			3.70	4.89		
224.40			-57.42	31609.7			-0.445	4.003
	248.48	310.25			3.85	4.81		
244.80			-119.20	29792.6			-0.924	3.773
	165.53	297.30			2.57	4.61		
265.20			-250.97	25987.2			-1.945	3.291
	306.59	273.45			4.75	4.24		
285.60			-217.83	21154.0			-1.688	2.679
	259.35	238.40			4.02	3.70		
306.00			-196.87	16859.0			-1.526	2.135

	179.53	198.61			2.78	3.08		
326.40			-215.96	12577.9			-1.674	1.593
	181.70	156.89			2.82	2.43		
346.80			-191.15	8355.8			-1.482	1.058
	124.04	117.79			1.92	1.83		
367.20			-184.90	4456.7			-1.433	0.564
	159.94	81.88			2.48	1.27		
387.60			-106.84	1418.7			-0.828	0.180
	132.74	41.32			2.06	0.64		
408.00			-15.41	95.9			-0.119	0.012
	16.00	0.59			0.42	0.02		
420.00			0.00	0.3			0.000	0.000

MOMENT AT ZERO SHEAR= 32048.3 FOOT-TONS LOCATED 209.188 FT FROM FP

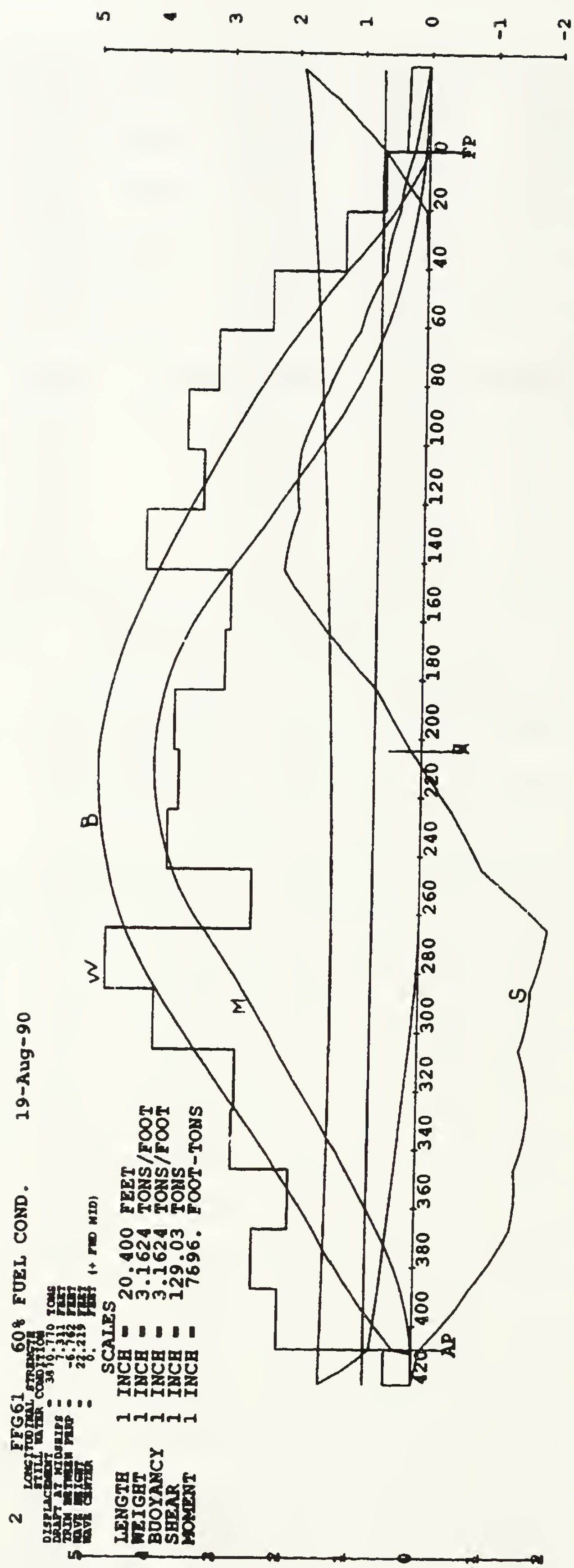

Figure B-3: SHCP Results, 60% Fuel, Seastate 0

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MINIMUM OPERATING CONDITION, SEASTATE 0

                         SSSS     HH        HH       CCCC      PPPPPPP
                        SSSSSS    HH        HH      CCCCCC     PPPPPPPP
                      SS    SS   HH        HH     CC    CC    PP     PP
                    SS      SS  HH        HH    CC      CC   PP      PP
                    SS         HH        HH    CC      CC   PP      PP
                    SSSS      HHHHHHHHHH    CC         PPPPPPPP
                     SSSS    HHHHHHHHHH    CC         PPPPPPP
                SS      SS   HH        HH   CC      CC   PP
               SS       SS  HH        HH   CC      CC   PP
               SS     SS   HH        HH   CC     CC    PP
               SSSSSS     HH        HH    CCCCCC     PP
                SSSS      HH        HH     CCCC      PP


                     SHIP HULL CHARACTERISTICS PROGRAM


1SHIP-     FFG61 MIN. OP. COND. (COND. B)      SERIAL NUMBER-    2  DATE-15-Aug-90

0DESIGN DISPLACEMENT              3817.301 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT    (+ ABOVE BL)       15.441 FT |
 DESIGN LCG      (+ FWD MID)        -7.700 FT | DESIGN LCB   (+ F MID)       -7.700 FT
 DESIGN VCG      (+ ABOVE BL)       0.     FT | DESIGN VCB   (+ ABL)          9.720 FT
 DESIGN TCG      (+ STBD)           0.     FT | DESIGN TCB   (+ STBD)         0.    FT
 DESIGN TRIM     (+ BY STERN)        1.984 FT | DESIGN LIST  (+ STBD)         0.    DEG
0LENGTH OVERALL                    447.780 FEET
 LENGTH BETWEEN PERPENDICULARS     408.000 FEET
 LENGTH ON DESIGN WATERLINE        409.498 FEET
0STATION OF MAX AREA  (AT DWL)     214.460 FEET FROM FP
 BEAM AT STATION OF MAX AREA        45.363 FEET
 SECTION AREA COEFFICIENT           0.7598
 PRISMATIC COEFFICIENT              0.6133
 BLOCK COEFFICIENT                  0.4660
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =         20 and LBP =         20
0                Approximate Bounding Cube Values:
+         ________________________________________________________
         Forward X location            -27.948 Ft  (+ Aft FP)
         After   X location            419.832 Ft  (+ Aft FP)
         Maximum Y value on Station     46.938 Ft
         Minimum Z value on Station      0.    Ft  (+ Abv BL)
         Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0                Work List and Requested Options:
+_____________________________________________________________________
     1     3 Longitudinal Strength

   KK      3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT   3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF    F Plots will be SHCP NEUTRAL PLOTFILE format
   KKAP    3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP  0 NO Appendage PLOTS
   IPLCON  0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV  0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT   0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-     FFG61 MIN. OP. COND. (COND. B)      SERIAL NUMBER-    2  DATE-15-Aug-90
0                         LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS   0.    FEET (+ FWD)
 WAVE LENGTH/LBP              1.000
 WAVE HEIGHT=1.1*SQRT(LBP)    22.22 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =         20 and LBP =         20
```

0 WEIGHT STATION (FROM FP)	WEIGHT (TONS)	LCG OF WEIGHT FROM AMIDSHIPS (FT,+FWD)	— SECTION MODULUS — (INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	141.81	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	296.49	91.80		
142.80	215.79	71.40		
163.20	139.07	51.00		
183.60	174.84	30.60		
204.00	224.72	10.20		
224.40	237.78	-10.20		
244.80	239.55	-30.60		
265.20	248.03	-51.00		
285.60	296.35	-71.40		
306.00	249.48	-91.80		
326.40	165.99	-112.20		
346.80	188.03	-132.60		
367.20	98.70	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

1SHIP- FFG61 MIN. OP. COND. (COND. B) SERIAL NUMBER- 2 DATE-15-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	14.865	0.	195.718	15.469	528.494
-23.914	14.876	0.	200.200	15.481	531.956
-19.432	14.888	0.	204.682	15.493	534.555
-14.949	14.900	0.	209.165	15.505	535.232
-10.467	14.912	0.	213.647	15.517	535.246
-5.985	14.925	0.	218.129	15.529	534.597
-1.503	14.937	0.	222.612	15.541	533.285
2.980	14.949	6.666	227.094	15.553	531.311
7.462	14.961	17.515	231.576	15.566	528.673
11.944	14.973	29.507	236.058	15.578	525.372
16.427	14.985	42.640	240.541	15.590	521.409
20.909	14.997	56.914	245.023	15.602	516.821
25.391	15.009	72.331	249.505	15.614	512.106
29.873	15.021	88.889	253.988	15.626	506.340
34.356	15.033	106.589	258.470	15.638	499.523
38.838	15.045	125.431	262.952	15.650	491.653
43.320	15.058	143.674	267.434	15.662	482.733
47.803	15.070	160.550	271.917	15.674	472.760
52.285	15.082	177.093	276.399	15.687	461.736
56.767	15.094	193.302	280.881	15.699	449.660
61.249	15.106	209.178	285.364	15.711	436.533
65.732	15.118	224.721	289.846	15.723	422.650
70.214	15.130	239.930	294.328	15.735	408.516
74.696	15.142	254.805	298.810	15.747	394.134
79.179	15.154	269.347	303.293	15.759	379.506
83.661	15.166	283.101	307.775	15.771	364.631
88.143	15.179	296.117	312.257	15.783	349.510
92.625	15.191	308.975	316.740	15.795	334.141
97.108	15.203	321.676	321.222	15.807	318.526

101.590	15.215	334.221	325.704	15.820	302.663
106.072	15.227	346.608	330.186	15.832	286.713
110.555	15.239	358.839	334.669	15.844	271.064
115.037	15.251	370.912	339.151	15.856	255.730
119.519	15.263	382.828	343.633	15.868	240.712
124.001	15.275	394.578	348.116	15.880	226.010
128.484	15.287	406.048	352.598	15.892	211.623
132.966	15.299	417.208	357.080	15.904	197.552
137.448	15.312	428.055	361.562	15.916	183.797
141.931	15.324	438.591	366.045	15.928	170.358
146.413	15.336	448.816	370.527	15.941	157.713
150.895	15.348	458.729	375.009	15.953	144.707
155.377	15.360	468.330	379.491	15.965	131.048
159.860	15.372	477.621	383.974	15.977	116.735
164.342	15.384	486.459	388.456	15.989	101.768
168.824	15.396	494.371	392.938	16.001	86.148
173.306	15.408	501.648	397.421	16.013	69.875
177.789	15.420	508.289	401.903	16.025	52.948
182.271	15.433	514.294	406.385	16.037	35.368
186.753	15.445	519.663	410.867	16.049	0.
191.236	15.457	524.397	415.350	16.061	0.
195.718	15.469	528.494	419.831	16.074	0.

1SHIP- FFG61 MIN. OP. COND. (COND. B) SERIAL NUMBER- 2 DATE-15-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DISPLACEMENT 3815.41 TONS SW LCG -5.524 FT FROM AMIDSHIPS (+ FWD)

0LOCATION WEIGHT BUOYANCY SHEAR BENDING MOM WEIGHT BUOYANCY SHEAR MOMENT

STRESS (TONS/IN**2)

FT FM FP	TONS	TONS	TONS	FOOT-TONS	ORD	ORD	ORD	ORD
DECK	KEEL							
-29.00			0.	0.			0.	0.
	28.68	0.00			0.32	0.00		
0.			28.68	405.8			0.226	0.052
	42.43	14.97			0.67	0.24		
20.40			56.14	1325.6			0.441	0.170
	80.51	54.01			1.27	0.85		
40.80			82.64	2819.1			0.650	0.362
	141.81	100.31			2.23	1.58		
61.20			124.14	5002.5			0.976	0.643
	204.55	141.99			3.22	2.23		
81.60			186.70	8240.4			1.468	1.059
	233.93	178.64			3.68	2.81		
102.00			241.99	12670.8			1.903	1.628
	296.49	211.67			4.66	3.33		
122.40			326.81	18527.2			2.570	2.380
	215.79	242.49			3.39	3.81		
142.80			300.11	24971.6			2.360	3.208
	139.07	269.87			2.19	4.24		
163.20			169.32	29803.1			1.331	3.829
	174.84	292.15			2.75	4.59		
183.60			52.00	32091.9			0.409	4.123
	224.72	306.74			3.53	4.82		
204.00			-30.02	32334.4			-0.236	4.154
	237.78	311.61			3.74	4.90		
224.40			-103.85	30967.1			-0.817	3.979
	239.55	306.55			3.77	4.82		
244.80			-170.85	28149.7			-1.343	3.617
	248.03	293.75			3.90	4.62		
265.20			-216.57	24168.6			-1.703	3.105
	296.35	270.08			4.66	4.25		
285.60			-190.30	19967.3			-1.496	2.565
	249.48	235.25			3.92	3.70		
306.00			-176.07	16165.7			-1.384	2.077

	165.99	195.72			2.61	3.08		
326.40			-205.80	12200.9			-1.618	1.568
	188.03	154.28			2.96	2.43		
346.80			-172.04	8277.5			-1.353	1.063
	98.70	115.45			1.55	1.82		
367.20			-188.79	4534.3			-1.484	0.583
	159.94	79.82			2.52	1.26		
387.60			-108.67	1438.4			-0.854	0.185
	132.74	39.58			2.09	0.62		
408.00			-15.51	96.8			-0.122	0.012
	16.00	0.49			0.43	0.01		
420.00			0.	0.9			0.	0.000

MOMENT AT ZERO SHEAR= 32441.3 FOOT-TONS LOCATED 196.834 FT FROM FP

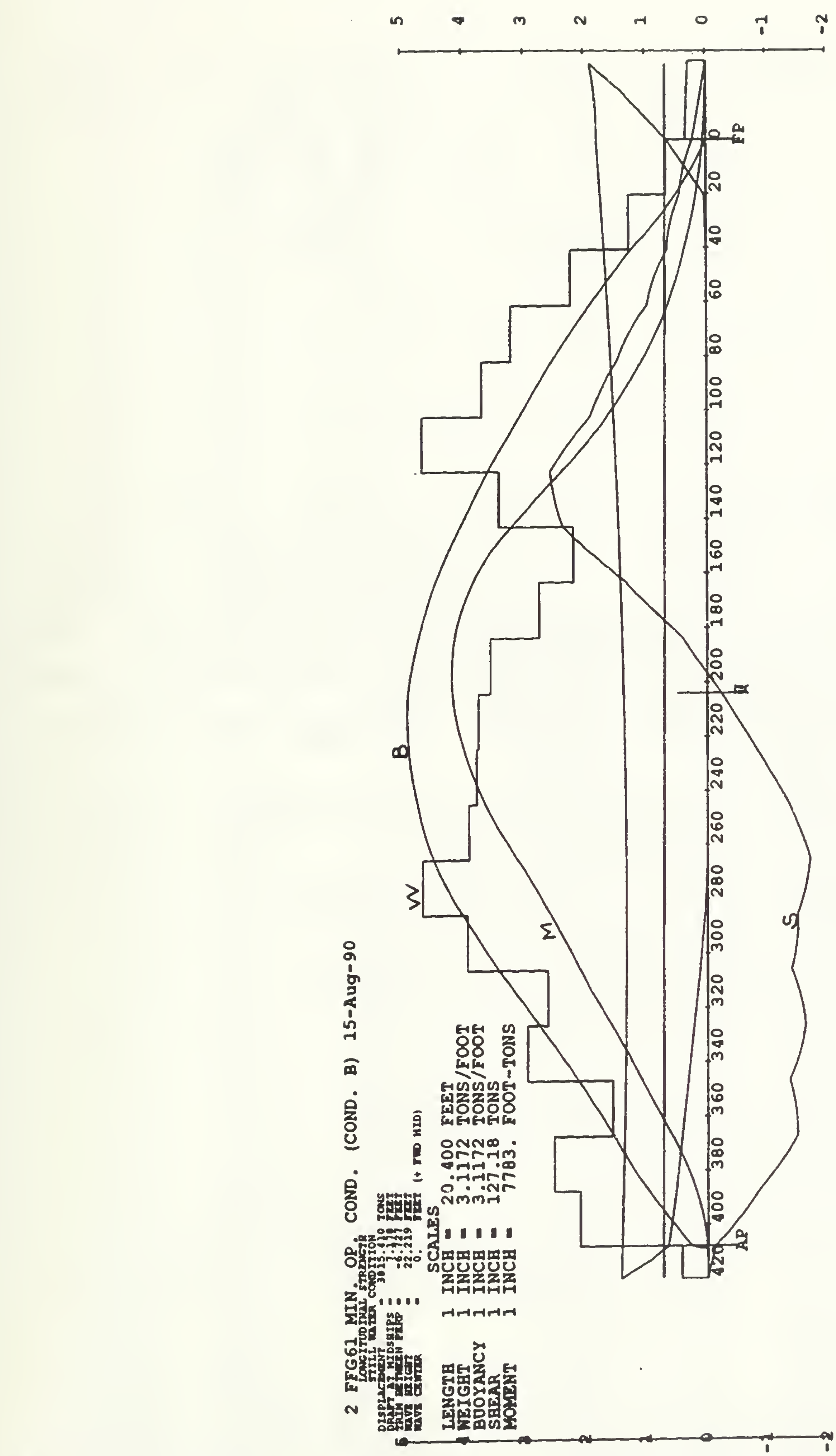

Figure B-4: SHCP Results, Minimum Operating Condition, Seastate 0

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FULL LOAD, SEASTATE 2

                         SSSS     HH       HH      CCCC      PPPPPPP
                        SSSSSS    HH       HH     CCCCCC     PPPPPPPP
                      SS    SS   HH       HH   CC     CC    PP     PP
                    SS      SS  HH       HH  CC       CC   PP      PP
                    SS         HH       HH  CC       CC  PP      PP
                    SSSS      HHHHHHHHHH  CC             PPPPPPPP
                     SSSS    HHHHHHHHHH  CC            PPPPPPP
                SS     SS   HH       HH  CC       CC  PP
               SS      SS  HH       HH  CC       CC  PP
               SS    SS   HH       HH   CC     CC   PP
               SSSSSS    HH       HH    CCCCCC    PP
                SSSS     HH       HH     CCCC      PP


                         SHIP HULL CHARACTERISTICS PROGRAM


0DESIGN DISPLACEMENT              3987.720 TONS SW at DENSITY =     35.000 FT3/TON
 DESIGN DRAFT    (+ ABOVE BL)       15.935 FT |
 DESIGN LCG      (+ FWD MID)        -6.110 FT | DESIGN LCB  (+ F MID)       -6.110 FT
 DESIGN VCG      (+ ABOVE BL)        0.    FT | DESIGN VCB  (+ ABL)          9.971 FT
 DESIGN TCG      (+ STBD)            0.    FT | DESIGN TCB  (+ STBD)         0.    FT
 DESIGN TRIM     (+ BY STERN)        0.993 FT | DESIGN LIST (+ STBD)         0.    DEG
0LENGTH OVERALL                    447.780 FEET
 LENGTH BETWEEN PERPENDICULARS     408.000 FEET
 LENGTH ON DESIGN WATERLINE        409.645 FEET
0STATION OF MAX AREA  (AT DWL)     211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA        45.407 FEET
 SECTION AREA COEFFICIENT           0.7667
 PRISMATIC COEFFICIENT              0.6160
 BLOCK COEFFICIENT                  0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20
0               Approximate Bounding Cube Values:
+       _____________________________________________________
        Forward X location            -27.948 Ft  (+ Aft FP)
        After   X location            419.832 Ft  (+ Aft FP)
        Maximum Y value on Station     46.938 Ft
        Minimum Z value on Station      0.    Ft  (+ Abv BL)
        Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0               Work List and Requested Options:
+______________________________________________________________________
     1    3 Longitudinal Strength

   KK     3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT  3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF   F Plots will be SHCP NEUTRAL PLOTFILE format
   KKAP   3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP 0 NO Appendage PLOTS
   IPLCON 0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV 0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT  0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-    FFG61 FULL LOAD COND. (COND. D)     SERIAL NUMBER-   15  DATE-10-Aug-90
0                          LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS    0.    FEET (+ FWD)
 WAVE LENGTH/LBP             1.000
 WAVE HEIGHT INPUT            1.01 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20

0 WEIGHT    WEIGHT    LCG OF WEIGHT      -- SECTION MODULUS --
```

STATION (FROM FP)	(TONS)	FROM AMIDSHIPS (FT,+FWD)	(INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	106.63	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	282.89	91.80		
142.80	290.51	71.40		
163.20	196.93	51.00		
183.60	191.49	30.60		
204.00	241.54	10.20		
224.40	255.69	-10.20		
244.80	245.90	-30.60		
265.20	233.93	-51.00		
285.60	302.47	-71.40		
306.00	255.69	-91.80		
326.40	179.53	-112.20		
346.80	181.70	-132.60		
367.20	124.04	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 15 DATE-10-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	16.231	0.	195.718	15.557	532.188
-23.914	16.247	0.	200.200	15.557	535.227
-19.432	16.265	0.	204.682	15.559	537.488
-14.949	16.277	0.	209.165	15.570	537.955
-10.467	16.288	0.	213.647	15.581	537.859
-5.985	16.298	0.	218.129	15.592	537.201
-1.503	16.309	0.	222.612	15.602	535.980
2.980	16.312	8.835	227.094	15.620	534.196
7.462	16.312	21.639	231.576	15.641	531.849
11.944	16.313	35.516	236.058	15.662	528.940
16.427	16.313	50.465	240.541	15.683	525.468
20.909	16.312	66.487	245.023	15.705	521.473
25.391	16.301	83.580	249.505	15.734	517.446
29.873	16.291	101.747	253.988	15.764	512.417
34.356	16.280	120.986	258.470	15.794	506.387
38.838	16.270	141.297	262.952	15.824	499.355
43.320	16.255	160.907	267.434	15.857	491.321
47.803	16.235	178.999	271.917	15.893	482.286
52.285	16.216	196.615	276.399	15.930	472.250
56.767	16.197	213.754	280.881	15.966	461.211
61.249	16.178	230.418	285.364	16.002	449.171
65.732	16.152	246.606	289.846	16.042	436.393
70.214	16.127	262.318	294.328	16.082	423.327
74.696	16.101	277.554	298.810	16.122	409.980
79.179	16.075	292.313	303.293	16.161	396.351
83.661	16.048	306.118	307.775	16.201	382.439
88.143	16.020	319.039	312.257	16.241	368.246
92.625	15.991	331.696	316.740	16.281	353.771
97.108	15.962	344.089	321.222	16.321	339.014
101.590	15.933	356.218	325.704	16.361	323.974
106.072	15.905	368.083	330.186	16.398	308.764
110.555	15.876	379.684	334.669	16.435	293.770

115.037	15.848	391.022	339.151	16.472	279.010
119.519	15.819	402.095	343.633	16.509	264.487
124.001	15.792	412.885	348.116	16.544	250.198
128.484	15.766	423.339	352.598	16.574	236.145
132.966	15.741	433.474	357.080	16.604	222.328
137.448	15.716	443.291	361.562	16.635	208.746
141.931	15.691	452.790	366.045	16.665	195.399
146.413	15.671	461.970	370.527	16.689	182.806
150.895	15.652	470.831	375.009	16.711	169.730
155.377	15.634	479.374	379.491	16.732	155.858
159.860	15.615	487.599	383.974	16.754	141.189
164.342	15.599	495.374	388.456	16.773	125.724
168.824	15.589	502.299	392.938	16.784	109.463
173.306	15.579	508.668	397.421	16.796	92.405
177.789	15.569	514.483	401.903	16.807	74.551
182.271	15.559	519.742	406.385	16.818	55.901
186.753	15.556	524.446	410.867	16.824	0.
191.236	15.556	528.595	415.350	16.827	0.
195.718	15.557	532.188	419.831	16.828	0.

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 15 DATE-10-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING
0WAVE HEIGHT, 1.01 FT CENTER 0. FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000
DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

STRESS (TONS/IN**2)

0LOCATION FT FM FP DECK	WEIGHT TONS KEEL	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-29.00			0.	0.			0.	0.
	28.68	0.01			0.30	0.00		
0.			28.67	405.8			0.216	0.050
	42.43	18.02			0.64	0.27		
20.40			53.09	1302.9			0.399	0.160
	80.51	61.62			1.21	0.93		
40.80			71.98	2663.7			0.541	0.327
	106.63	111.44			1.60	1.68		
61.20			67.16	4161.9			0.505	0.512
	204.55	155.03			3.08	2.33		
81.60			116.68	6106.4			0.878	0.751
	233.93	191.85			3.52	2.89		
102.00			158.76	8972.6			1.194	1.103
	282.89	223.61			4.26	3.36		
122.40			218.04	12867.2			1.640	1.582
	290.51	252.02			4.37	3.79		
142.80			256.53	17752.9			1.930	2.182
	196.93	276.63			2.96	4.16		
163.20			176.83	22211.8			1.330	2.730
	191.49	296.28			2.88	4.46		
183.60			72.05	24777.8			0.542	3.046
	241.54	309.05			3.63	4.65		
204.00			4.53	25574.9			0.034	3.144
	255.69	313.18			3.85	4.71		
224.40			-52.96	25079.0			-0.398	3.083
	245.90	308.60			3.70	4.64		
244.80			-115.66	23345.5			-0.870	2.870
	233.93	297.42			3.52	4.48		
265.20			-179.15	20312.4			-1.348	2.497
	302.47	276.10			4.55	4.15		
285.60			-152.78	16880.2			-1.149	2.075
	255.69	244.06			3.85	3.67		
306.00			-141.16	13821.9			-1.062	1.699
	179.53	207.08			2.70	3.12		
326.40			-168.71	10595.7			-1.269	1.302
	181.70	167.62			2.73	2.52		

346.80			-154.63	7231.1			-1.163	0.889
	124.04	129.85			1.87	1.95		
367.20			-160.43	3955.8			-1.207	0.486
	159.94	94.27			2.41	1.42		
387.60			-94.76	1290.1			-0.713	0.159
	132.74	52.60			2.00	0.79		
408.00			-14.62	95.3			-0.110	0.012
	16.00	1.38			0.41	0.04		
420.00			0.	0.1			0.	0.000

.

MOMENT AT ZERO SHEAR= 25578.5 FOOT-TONS LOCATED 205.608 FT FROM FP
1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 15 DATE-10-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - HOGGING
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

.

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	14.558	0.	195.718	16.280	565.006
-23.914	14.562	0.	200.200	16.300	568.982
-19.432	14.565	0.	204.682	16.320	571.962
-14.949	14.573	0.	209.165	16.329	572.816
-10.467	14.584	0.	213.647	16.339	572.880
-5.985	14.595	0.	218.129	16.349	572.154
-1.503	14.605	0.	222.612	16.359	570.637
2.980	14.623	6.248	227.094	16.363	568.329
7.462	14.643	16.619	231.576	16.362	565.231
11.944	14.664	28.186	236.058	16.361	561.343
16.427	14.685	40.951	240.541	16.361	556.664
20.909	14.707	54.912	245.023	16.360	551.232
25.391	14.738	70.071	249.505	16.350	545.541
29.873	14.768	86.427	253.988	16.341	538.733
34.356	14.799	103.980	258.470	16.331	530.807
38.838	14.830	122.730	262.952	16.322	521.764
43.320	14.866	140.966	267.434	16.309	511.604
47.803	14.906	157.959	271.917	16.293	500.326
52.285	14.945	174.728	276.399	16.278	487.931
56.767	14.985	191.275	280.881	16.262	474.418
61.249	15.025	207.599	285.364	16.246	459.788
65.732	15.071	223.700	289.846	16.227	444.365
70.214	15.117	239.579	294.328	16.208	428.708
74.696	15.163	255.234	298.810	16.189	412.824
79.179	15.209	270.667	303.293	16.170	396.711
83.661	15.257	285.441	307.775	16.151	380.370
88.143	15.306	299.586	312.257	16.132	363.801
92.625	15.356	313.649	316.740	16.114	347.004
97.108	15.405	327.631	321.222	16.095	329.979
101.590	15.455	341.533	325.704	16.076	312.726
106.072	15.505	355.354	330.186	16.060	295.459
110.555	15.554	369.094	334.669	16.045	278.581
115.037	15.604	382.753	339.151	16.029	262.100
119.519	15.654	396.332	343.633	16.014	246.016
124.001	15.703	409.812	348.116	16.001	230.329
128.484	15.749	423.003	352.598	15.992	215.039
132.966	15.796	435.851	357.080	15.983	200.146
137.448	15.842	448.358	361.562	15.974	185.650
141.931	15.889	460.523	366.045	15.965	171.551
146.413	15.930	472.345	370.527	15.962	158.345
150.895	15.970	483.825	375.009	15.962	144.864
155.377	16.010	494.964	379.491	15.962	130.809
159.860	16.050	505.760	383.974	15.962	116.182
164.342	16.088	516.062	388.456	15.964	100.982
168.824	16.120	525.316	392.938	15.974	85.208
173.306	16.151	533.816	397.421	15.984	68.862

177.789	16.182	541.563	401.903	15.994	51.944
182.271	16.214	548.555	406.385	16.004	34.452
186.753	16.238	554.793	410.867	16.018	0.
191.236	16.259	560.277	415.350	16.036	0.
195.718	16.280	565.006	419.831	16.056	0.

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 15 DATE-10-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - HOGGING

0WAVE HEIGHT, 1.01 FT CENTER 0. FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000

DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION	WEIGHT	BUOYANCY	SHEAR	BENDING MOM	WEIGHT	BUOYANCY	SHEAR	MOMENT
STRESS (TONS/IN**2)								
FT FM FP	TONS	TONS	TONS	FOOT-TONS	ORD	ORD	ORD	ORD
DECK	KEEL							
-29.00			0.	0.			0.	0.
	28.68	0.00			0.30	0.00		
0.			28.68	405.8			0.216	0.050
	42.43	14.32			0.64	0.22		
20.40			56.79	1330.3			0.427	0.164
	80.51	52.59			1.21	0.79		
40.80			84.71	2850.9			0.637	0.350
	106.63	98.94			1.60	1.49		
61.20			92.40	4732.8			0.695	0.582
	204.55	141.96			3.08	2.14		
81.60			154.99	7327.0			1.166	0.901
	233.93	181.27			3.52	2.73		
102.00			207.66	11089.3			1.562	1.363
	282.89	218.02			4.26	3.28		
122.40			272.53	16048.9			2.050	1.973
	290.51	253.26			4.37	3.81		
142.80			309.78	22045.7			2.330	2.710
	196.93	284.90			2.96	4.29		
163.20			221.80	27518.1			1.669	3.383
	191.49	310.86			2.88	4.68		
183.60			102.44	30861.9			0.771	3.794
	241.54	327.81			3.63	4.93		
204.00			16.16	32092.8			0.122	3.945
	255.69	333.48			3.85	5.02		
224.40			-61.63	31627.1			-0.464	3.888
	245.90	327.57			3.70	4.93		
244.80			-143.30	29518.6			-1.078	3.629
	233.93	312.46			3.52	4.70		
265.20			-221.83	25759.9			-1.669	3.167
	302.47	285.50			4.55	4.30		
285.60			-204.86	21350.5			-1.541	2.625
	255.69	246.74			3.85	3.71		
306.00			-195.90	17191.3			-1.474	2.113
	179.53	203.32			2.70	3.06		
326.40			-219.69	12876.1			-1.653	1.583
	181.70	158.41			2.73	2.38		
346.80			-196.40	8557.4			-1.478	1.052
	124.04	117.01			1.87	1.76		
367.20			-189.37	4556.4			-1.425	0.560
	159.94	79.82			2.41	1.20		
387.60			-109.25	1446.9			-0.822	0.178
	132.74	39.03			2.00	0.59		
408.00			-15.54	98.9			-0.117	0.012
	16.00	0.46			0.41	0.01		
420.00			0.	3.0			0.	0.000

MOMENT AT ZERO SHEAR= 32127.0 FOOT-TONS LOCATED 208.239 FT FROM FP

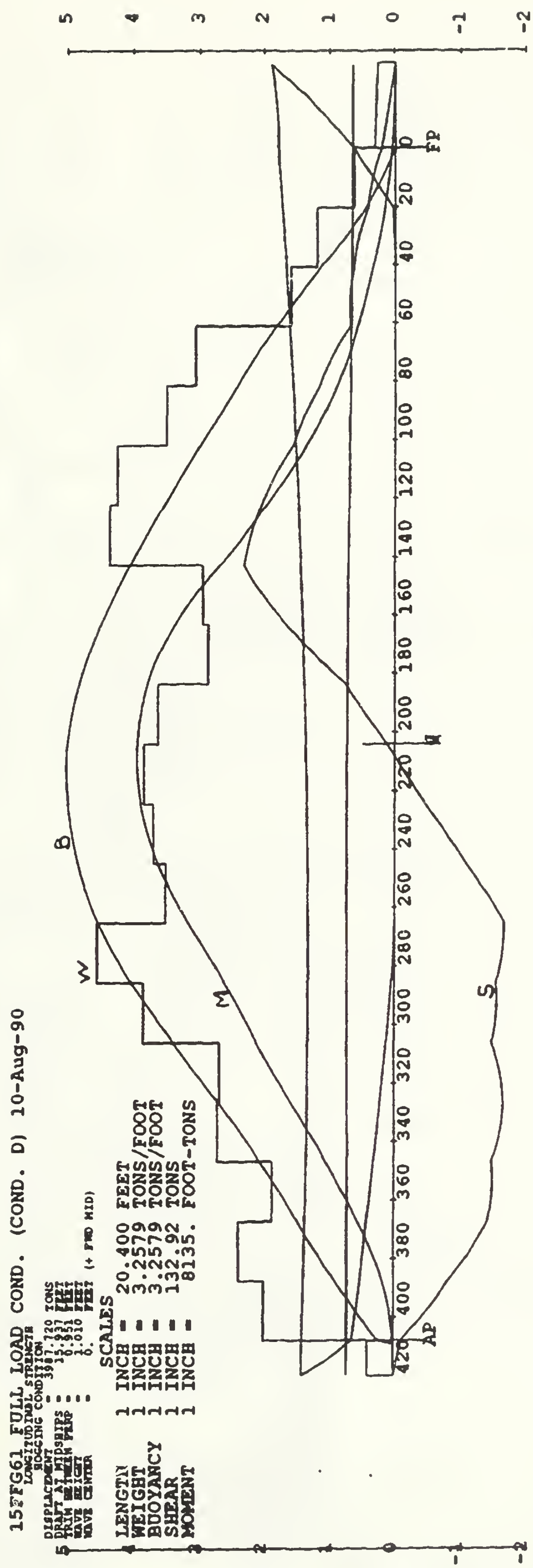

Figure B-5: SHCP Results, Full Load, Seastate 2, Hogging

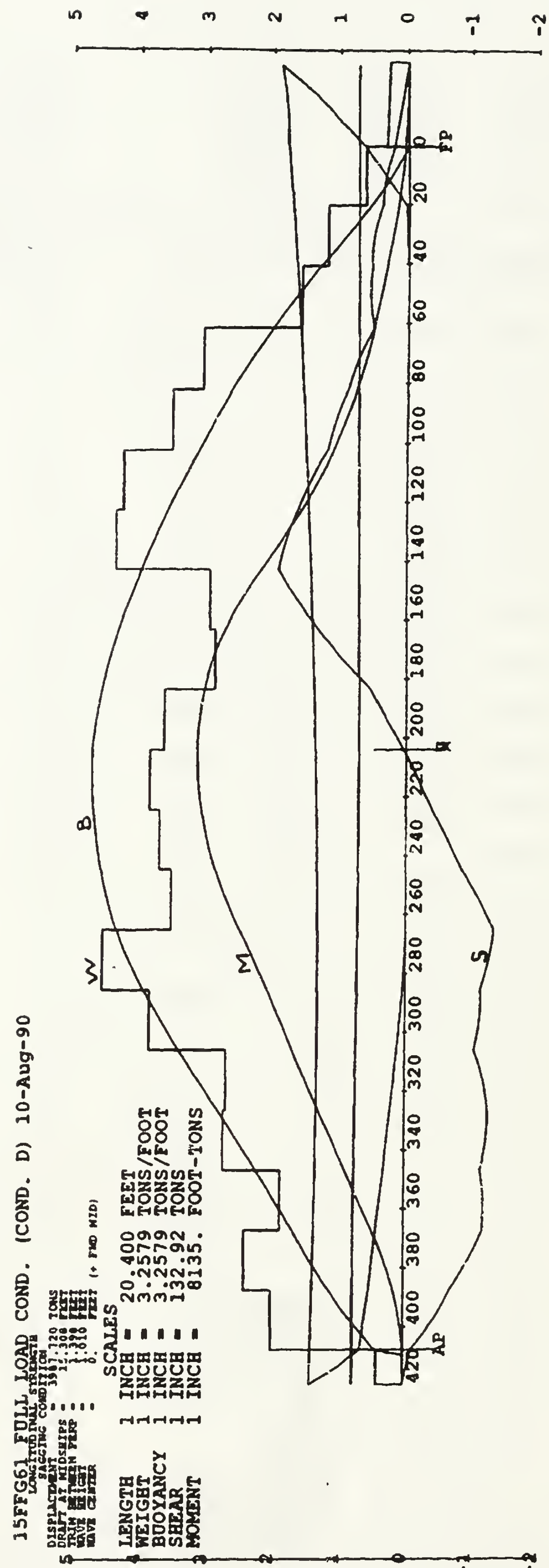

Figure B-6: SHCP Results, Full Load, Seastate 2, Sagging

FULL LOAD, SEASTATE 4

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                       SSSS      HH       HH      CCCC      PPPPPPP
                      SSSSSS     HH       HH     CCCCCC     PPPPPPPP
                     SS    SS    HH       HH    CC    CC    PP     PP
                    SS      SS   HH       HH   CC      CC   PP      PP
                    SS           HH       HH   CC      CC   PP      PP
                    SSSS         HHHHHHHHHH    CC           PPPPPPPP
                     SSSS        HHHHHHHHHH    CC           PPPPPPP
                  SS      SS     HH       HH   CC      CC   PP
                  SS      SS     HH       HH   CC      CC   PP
                  SS     SS      HH       HH    CC    CC    PP
                  SSSSSS         HH       HH     CCCCCC     PP
                   SSSS          HH       HH      CCCC      PP
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SHIP HULL CHARACTERISTICS PROGRAM

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0DESIGN DISPLACEMENT             3987.720 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT    (+ ABOVE BL)      15.935 FT |
 DESIGN LCG      (+ FWD MID)       -6.110 FT | DESIGN LCB   (+ F MID)     -6.110 FT
 DESIGN VCG      (+ ABOVE BL)       0.    FT | DESIGN VCB   (+ ABL)        9.971 FT
 DESIGN TCG      (+ STBD)           0.    FT | DESIGN TCB   (+ STBD)       0.    FT
 DESIGN TRIM     (+ BY STERN)       0.993 FT | DESIGN LIST  (+ STBD)       0.    DEG
0LENGTH OVERALL                   447.780 FEET
 LENGTH BETWEEN PERPENDICULARS    408.000 FEET
 LENGTH ON DESIGN WATERLINE       409.645 FEET
0STATION OF MAX AREA  (AT DWL)    211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA       45.407 FEET
 SECTION AREA COEFFICIENT          0.7667
 PRISMATIC COEFFICIENT             0.6160
 BLOCK COEFFICIENT                 0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =        20
0              Approximate Bounding Cube Values:
        Forward X location            -27.948 Ft  (+ Aft FP)
        After   X location            419.832 Ft  (+ Aft FP)
        Maximum Y value on Station     46.938 Ft
        Minimum Z value on Station      0.    Ft  (+ Abv BL)
        Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0              Work List and Requested Options:
+______________________________________________________________________
     1     3 Longitudinal Strength
   KK      3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT   3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF    F Plots will be SHCP NEUTRAL PLOTFILE format
   KKAP    3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP  0 NO Appendage PLOTS
   IPLCON  0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV  0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT   0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-     FFG61 FULL LOAD COND. (COND. D)      SERIAL NUMBER-   12  DATE- 9-Aug-90
0                      LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS   0.     FEET (+ FWD)
 WAVE LENGTH/LBP             1.000
 WAVE HEIGHT INPUT             6.20 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =        20

0  WEIGHT    WEIGHT   LCG OF WEIGHT      -- SECTION MODULUS --
   STATION  ( TONS )  FROM AMIDSHIPS          (INCH**2-FEET)
  (FROM FP)             (FT,+FWD)           DECK         KEEL
```

-29.00		
0.	28.68	218.15
20.40	42.43	193.80
40.80	80.51	173.40
61.20	106.63	153.00
81.60	204.55	132.60
102.00	233.93	112.20
122.40	282.89	91.80
142.80	290.51	71.40
163.20	196.93	51.00
183.60	191.49	30.60
204.00	241.54	10.20
224.40	255.69	-10.20
244.80	245.90	-30.60
265.20	233.93	-51.00
285.60	302.47	-71.40
306.00	255.69	-91.80
326.40	179.53	-112.20
346.80	181.70	-132.60
367.20	124.04	-153.00
387.60	159.94	-173.40
408.00	132.74	-193.80
420.00	16.00	-210.00

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 12 DATE- 9-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	20.443	0.	195.718	13.702	448.757
-23.914	20.500	0.	200.200	13.653	449.454
-19.432	20.563	0.	204.682	13.614	449.908
-14.949	20.593	0.	209.165	13.626	449.522
-10.467	20.607	0.	213.647	13.638	449.074
-5.985	20.621	0.	218.129	13.651	448.565
-1.503	20.635	4.390	222.612	13.663	447.994
2.980	20.604	20.897	227.094	13.710	447.361
7.462	20.549	40.107	231.576	13.781	446.667
11.944	20.494	60.004	236.058	13.852	445.911
16.427	20.439	80.586	240.541	13.923	445.093
20.909	20.376	101.854	245.023	13.996	444.273
25.391	20.253	123.808	249.505	14.119	444.185
29.873	20.129	146.448	253.988	14.242	443.390
34.356	20.006	169.774	258.470	14.364	441.889
38.838	19.882	193.786	262.952	14.487	439.681
43.320	19.728	216.384	267.434	14.630	436.756
47.803	19.548	236.609	271.917	14.793	433.145
52.285	19.369	255.694	276.399	14.957	428.817
56.767	19.190	273.641	280.881	15.120	423.783
61.249	19.010	290.448	285.364	15.283	418.042
65.732	18.795	306.116	289.846	15.471	411.806
70.214	18.579	320.646	294.328	15.659	405.231
74.696	18.363	334.036	298.810	15.848	398.314
79.179	18.147	346.287	303.293	16.036	391.054
83.661	17.924	356.849	307.775	16.227	383.453
88.143	17.693	365.988	312.257	16.422	375.509
92.625	17.462	374.482	316.740	16.617	367.224
97.108	17.230	382.330	321.222	16.811	358.596
101.590	16.999	389.534	325.704	17.006	349.627
106.072	16.774	396.093	330.186	17.188	340.222
110.555	16.549	402.007	334.669	17.368	330.624
115.037	16.324	407.276	339.151	17.547	320.866
119.519	16.099	411.900	343.633	17.727	310.946

124.001	15.883	415.889	348.116	17.895	300.865
128.484	15.683	419.540	352.598	18.038	290.623
132.966	15.484	422.975	357.080	18.181	280.220
137.448	15.284	426.193	361.562	18.324	269.656
141.931	15.084	429.195	366.045	18.466	258.930
146.413	14.917	431.980	370.527	18.568	248.448
150.895	14.758	434.549	375.009	18.655	236.873
155.377	14.599	436.901	379.491	18.742	223.902
159.860	14.440	439.037	383.974	18.829	209.538
164.342	14.294	440.874	388.456	18.903	193.780
168.824	14.187	442.322	392.938	18.922	176.627
173.306	14.080	443.663	397.421	18.940	158.082
177.789	13.972	444.897	401.903	18.959	138.141
182.271	13.865	446.023	406.385	18.977	116.807
186.753	13.799	447.042	410.867	18.965	30.250
191.236	13.751	447.953	415.350	18.930	0.
195.718	13.702	448.757	419.831	18.879	0.

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 12 DATE- 9-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING

0WAVE HEIGHT, 6.20 FT CENTER 0. FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000

DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION WEIGHT BUOYANCY SHEAR BENDING MOM WEIGHT BUOYANCY SHEAR MOMENT STRESS (TONS/IN**2)

FT FM FP TONS TONS TONS FOOT-TONS ORD ORD ORD ORD DECK KEEL

LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-29.00			0.	0.			0.	0.
	28.68	0.41			0.30	0.00		
0.			28.27	405.3			0.213	0.050
	42.43	30.76			0.64	0.46		
20.40			39.94	1191.0			0.300	0.146
	80.51	87.88			1.21	1.32		
40.80			32.57	2034.7			0.245	0.250
	106.63	145.34			1.60	2.19		
61.20			-6.14	2389.2			-0.046	0.294
	204.55	188.45			3.08	2.84		
81.60			9.96	2489.8			0.075	0.306
	233.93	217.06			3.52	3.27		
102.00			26.83	2902.4			0.202	0.357
	282.89	235.16			4.26	3.54		
122.40			74.56	3960.7			0.561	0.487
	290.51	246.27			4.37	3.71		
142.80			118.80	5948.1			0.894	0.731
	196.93	253.83			2.96	3.82		
163.20			61.90	7801.9			0.466	0.959
	191.49	258.55			2.88	3.89		
183.60			-5.16	8386.4			-0.039	1.031
	241.54	261.31			3.63	3.93		
204.00			-24.94	8083.0			-0.188	0.994
	255.69	261.68			3.85	3.94		
224.40			-30.93	7511.0			-0.233	0.923
	245.90	260.02			3.70	3.91		
244.80			-45.05	6732.7			-0.339	0.828
	233.93	257.92			3.52	3.88		
265.20			-69.03	5563.2			-0.519	0.684
	302.47	250.18			4.55	3.76		
285.60			-16.74	4667.9			-0.126	0.574
	255.69	234.72			3.85	3.53		
306.00			4.23	4509.3			0.032	0.554
	179.53	214.46			2.70	3.23		
326.40			-30.70	4201.4			-0.231	0.516
	181.70	190.19			2.73	2.86		
346.80			-39.19	3444.6			-0.295	0.423
	124.04	163.36			1.87	2.46		

367.20			-78.50	2196.9			-0.591	0.270
	159.94	133.43			2.41	2.01		
387.60			-51.99	807.2			-0.391	0.099
	132.74	90.49			2.00	1.36		
408.00			-9.74	90.0			-0.073	0.011
	16.00	6.26			0.41	0.16		
420.00			0.	2.3			0.	0.000

MOMENT AT ZERO SHEAR= 2395.5 FOOT-TONS LOCATED 59.111 FT FROM FP
MOMENT AT ZERO SHEAR= 2377.5 FOOT-TONS LOCATED 65.230 FT FROM FP
MOMENT AT ZERO SHEAR= 8390.4 FOOT-TONS LOCATED 182.064 FT FROM FP
MOMENT AT ZERO SHEAR= 4503.1 FOOT-TONS LOCATED 303.014 FT FROM FP
MOMENT AT ZERO SHEAR= 4513.3 FOOT-TONS LOCATED 307.927 FT FROM FP

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 12 DATE- 9-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - HOGGING
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	10.222	0.	195.718	18.129	649.702
-23.914	10.197	0.	200.200	18.207	656.154
-19.432	10.170	0.	204.682	18.273	660.994
-14.949	10.171	0.	209.165	18.277	662.842
-10.467	10.185	0.	213.647	18.281	663.248
-5.985	10.199	0.	218.129	18.285	662.210
-1.503	10.213	0.	222.612	18.289	659.729
2.980	10.265	2.874	227.094	18.252	655.805
7.462	10.336	9.176	231.576	18.188	650.438
11.944	10.407	16.447	236.058	18.123	643.629
16.427	10.478	24.686	240.541	18.058	635.376
20.909	10.556	33.893	245.023	17.991	625.714
25.391	10.686	44.068	249.505	17.871	615.284
29.873	10.816	55.211	253.988	17.751	603.458
34.356	10.946	67.323	258.470	17.630	590.236
38.838	11.075	80.403	262.952	17.510	575.616
43.320	11.234	93.94[illegible]	267.434	17 372	559.601
47.803	11.416	107.613	271.917	17.215	542.188
52.285	11.598	121.676	276.399	17.058	523.379
56.767	11.779	136.135	280.881	16.901	503.173
61.249	11.961	150.989	285.364	16.744	481.571
65.732	12.184	166.239	289.846	16.572	459.148
70.214	12.406	181.884	294.328	16.400	436.713
74.696	12.628	197.924	298.810	16.228	414.270
79.179	12.850	214.360	303.293	16.056	391.819
83.661	13.084	230.881	307.775	15.886	369.360
88.143	13.332	247.485	312.257	15.720	346.894
92.625	13.579	264.553	316.740	15.554	324.419
97.108	13.827	282.086	321.222	15.388	301.937
101.590	14.074	300.083	325.704	15.222	279.447
106.072	14.327	318.545	330.186	15.078	257.495
110.555	14.581	337.471	334.669	14.937	236.396
115.037	14.835	356.861	339.151	14.796	216.112
119.519	15.088	376.716	343.633	14.655	196.643
124.001	15.337	397.076	348.116	14.526	177.990
128.484	15.575	417.423	352.598	14.426	160.151
132.966	15.814	437.420	357.080	14.326	143.128
137.448	16.052	457.069	361.562	14.226	126.920
141.931	16.291	476.369	366.045	14.126	111.528
146.413	16.500	495.321	370.527	14.064	97.224
150.895	16.701	513.923	375.009	14.016	83.470
155.377	16.903	532.176	379.491	13.968	70.117
159.860	17.105	550.081	383.974	13.919	57.166
164.342	17.292	567.417	388.456	13.882	44.617

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     168.824     17.438     583.149          392.938     13.893      32.469
     173.306     17.585     597.556          397.421     13.903      20.722
     177.789     17.731     610.636          401.903     13.913       9.377
     182.271     17.877     622.391          406.385     13.924       0.
     186.753     17.974     632.820          410.867     13.959       0.
     191.236     18.052     641.924          415.350     14.014       0.
     195.718     18.129     649.702          419.831     14.082       0.
1SHIP-    FFG61 FULL LOAD COND. (COND. D)     SERIAL NUMBER-   12  DATE- 9-Aug-90
0         LONGITUDINAL STRENGTH CALCULATIONS - HOGGING
0WAVE HEIGHT,  6.20 FT   CENTER   0.   FT FROM AMIDSHIPS (+ FWD)  LENGTH/LBP 1.000
     DISPLACEMENT   3987.72 TONS SW     LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION  WEIGHT  BUOYANCY  SHEAR  BENDING MOM  WEIGHT  BUOYANCY  SHEAR   MOMENT
STRESS ( TONS/IN**2 )
 FT FM FP   TONS     TONS     TONS   FOOT-TONS    ORD      ORD      ORD      ORD
 DECK      KEEL
  -29.00                      0.          0.                        0.       0.
           28.68     0.                          0.30     0.
   0.                        28.68      405.8                       0.216    0.050
           42.43     8.36                        0.64     0.13
  20.40                      62.75     1371.6                       0.472    0.169
           80.51    33.77                        1.21     0.51
  40.80                     109.48     3181.4                       0.824    0.391
          106.63    68.75                        1.60     1.03
  61.20                     147.37     5865.1                       1.109    0.721
          204.55   108.66                        3.08     1.63
  81.60                     243.25     9921.3                       1.830    1.220
          233.93   152.58                        3.52     2.30
 102.00                     324.61    15791.1                       2.442    1.941
          282.89   201.05                        4.26     3.03
 122.40                     406.45    23335.0                       3.058    2.868
          290.51   253.83                        4.37     3.82
 142.80                     443.12    32090.2                       3.334    3.945
          196.93   304.39                        2.96     4.58
 163.20                     335.66    40116.2                       2.525    4.931
          191.49   347.79                        2.88     5.23
 183.60                     179.36    45431.3                       1.349    5.585
          241.54   376.17                        3.63     5.66
 204.00                      44.73    47751.8                       0.337    5.870
          255.69   385.82                        3.85     5.81
 224.40                     -85.40    47334.7                      -0.642    5.819
          245.90   375.80                        3.70     5.65
 244.80                    -215.30    44235.7                      -1.620    5.438
          233.93   349.36                        3.52     5.26
 265.20                    -330.73    38608.3                      -2.488    4.746
          302.47   306.87                        4.55     4.62
 285.60                    -335.13    31729.9                      -2.521    3.900
          255.69   250.24                        3.85     3.77
 306.00                    -329.68    24847.8                      -2.480    3.054
          179.53   190.66                        2.70     2.87
 326.40                    -340.81    17907.4                      -2.564    2.201
          181.70   133.04                        2.73     2.00
 346.80                    -292.15    11359.5                      -2.198    1.396
          124.04    84.01                        1.87     1.26
 367.20                    -252.12     5732.9                      -1.897    0.705
          159.94    44.67                        2.41     0.67
 387.60                    -136.85     1705.3                      -1.030    0.210
          132.74    11.89                        2.00     0.18
 408.00                     -16.00       96.0                      -0.120    0.012
           16.00     0.                          0.41     0.
 420.00                      0.          -0.1                       0.      -0.000

MOMENT AT ZERO SHEAR=    47908.7 FOOT-TONS   LOCATED   211.012 FT FROM FP
```

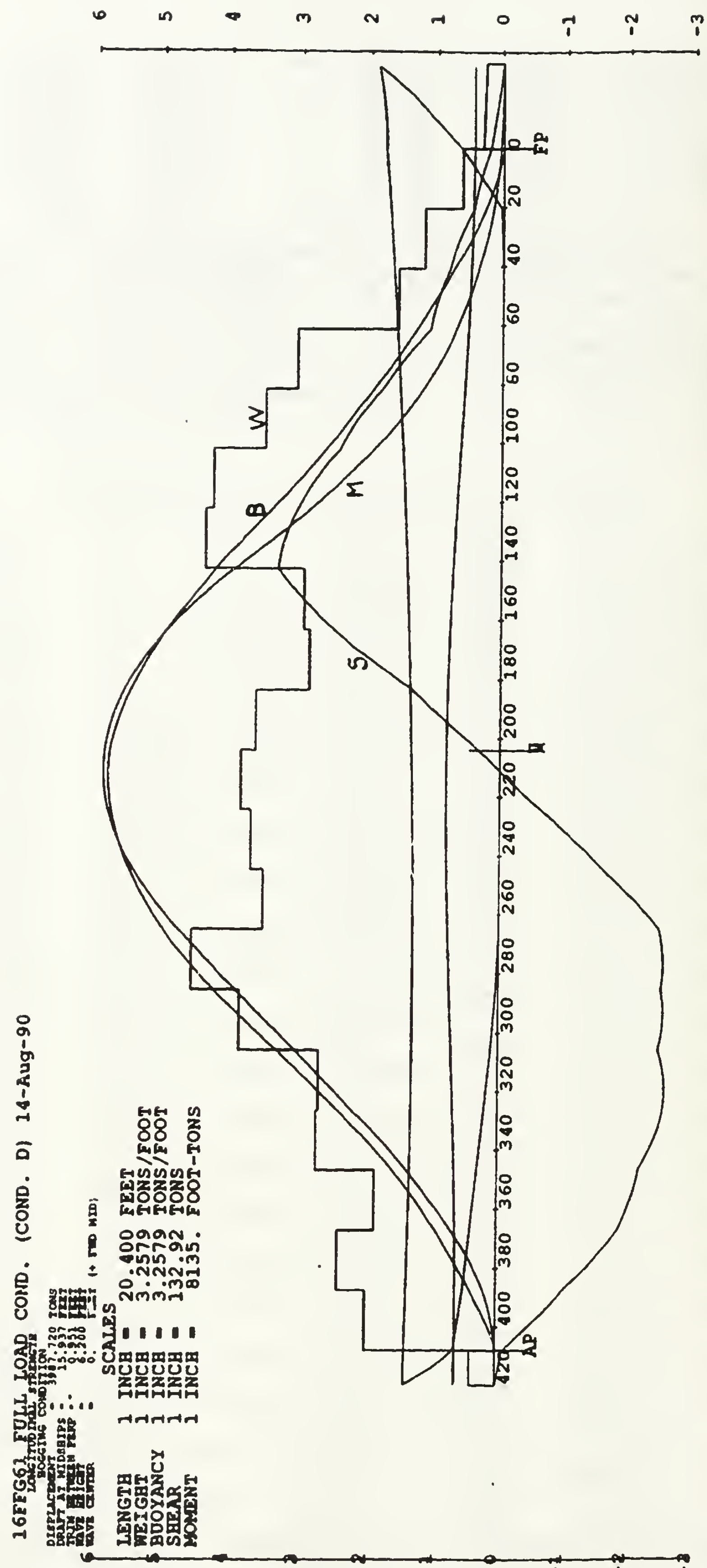

Figure B-7: SHCP Results, Full Load, Seastate 4, Hogging

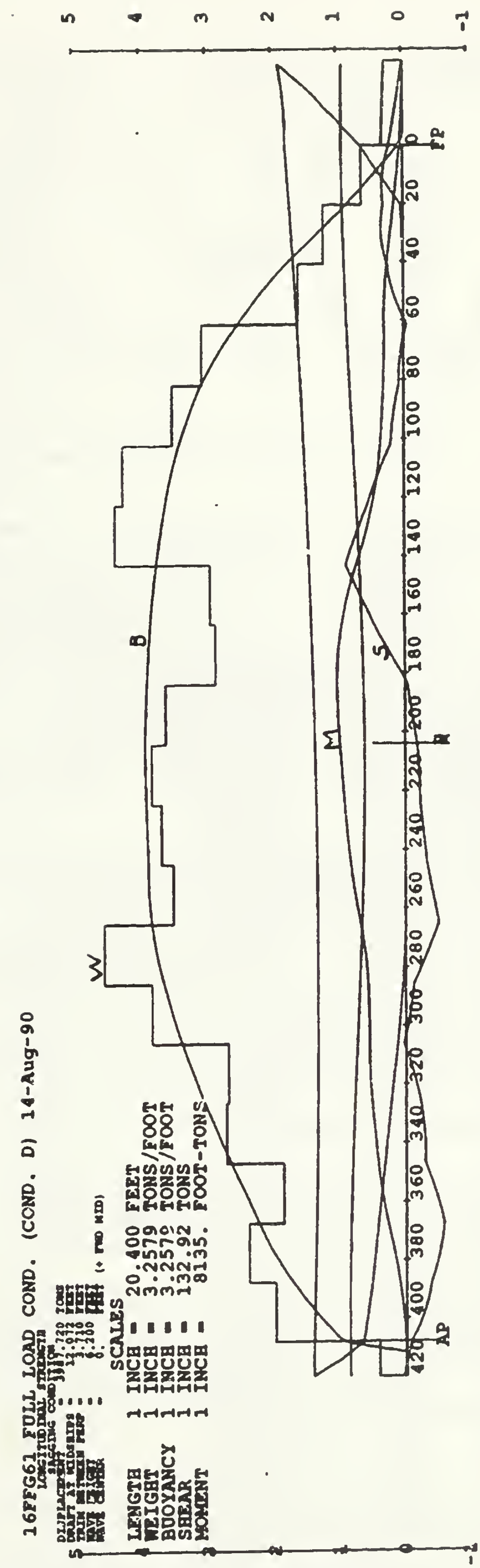

Figure B-8: SHCP Results, Full Load, Seastate 4, Sagging

FULL LOAD, SEASTATE 6

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                         SSSS     HH       HH      CCCC      PPPPPPP
                        SSSSSS    HH       HH     CCCCCC     PPPPPPPP
                      SS     SS  HH       HH    CC     CC    PP      PP
                    SS       SS  HH       HH  CC       CC  PP       PP
                    SS          HH       HH  CC       CC  PP       PP
                    SSSS       HHHHHHHHHH  CC            PPPPPPPP
                     SSSS     HHHHHHHHHH  CC           PPPPPPP
                SS       SS  HH       HH  CC       CC  PP
               SS        SS  HH       HH  CC       CC  PP
               SS    SS   HH       HH  CC     CC   PP
               SSSSSS    HH       HH   CCCCCC    PP
                SSSS     HH       HH    CCCC     PP
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SHIP HULL CHARACTERISTICS PROGRAM

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0DESIGN DISPLACEMENT                3987.720 TONS SW at DENSITY =      35.000 FT3/TON
 DESIGN DRAFT    (+ ABOVE BL)         15.935 FT |
 DESIGN LCG      (+ FWD MID)          -6.110 FT | DESIGN LCB  (+ F MID)       -6.110 FT
 DESIGN VCG      (+ ABOVE BL)          0.    FT | DESIGN VCB  (+ ABL)          9.971 FT
 DESIGN TCG      (+ STBD)              0.    FT | DESIGN TCB  (+ STBD)         0.    FT
 DESIGN TRIM     (+ BY STERN)          0.993 FT | DESIGN LIST (+ STBD)         0.    DEG
0LENGTH OVERALL                      447.780 FEET
 LENGTH BETWEEN PERPENDICULARS       408.000 FEET
 LENGTH ON DESIGN WATERLINE          409.645 FEET
0STATION OF MAX AREA  (AT DWL)       211.429 FEET FROM FP
 BEAM AT STATION OF MAX AREA          45.407 FEET
 SECTION AREA COEFFICIENT            0.7667
 PRISMATIC COEFFICIENT               0.6160
 BLOCK COEFFICIENT                   0.4723
0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20
0               Approximate Bounding Cube Values:
+       ________________________________________________________
        Forward X location            -27.948 Ft  (+ Aft FP)
        After   X location            419.832 Ft  (+ Aft FP)
        Maximum Y value on Station     46.938 Ft
        Minimum Z value on Station      0.    Ft  (+ Abv BL)
        Maximum Z value on Station     41.893 Ft  (+ Abv BL)
0               Work List and Requested Options:
+______________________________________________________________________
    1     3 Longitudinal Strength

   KK     3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT  3 Plot Main Hull both BODY PLAN and ISOMETRIC
   LDXF   F Plots will be SHCP NEUTRAL PLOTFILE format
   KKAP   3 NO Appendage INITIAL & INTERPOLATED OFFSETS Printed
   IPLTAP 0 NO Appendage PLOTS
   IPLCON 0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV 0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT  0 Input/Output units selected are ENGLISH-ENGLISH
1SHIP-    FFG61 FULL LOAD COND. (COND. D)      SERIAL NUMBER-    13  DATE- 9-Aug-90
0                        LONGITUDINAL STRENGTH CALCULATIONS
0WAVE CENTER FROM AMIDSHIPS   0.    FEET (+ FWD)
 WAVE LENGTH/LBP             1.000
 WAVE HEIGHT INPUT           16.40 FEET

0Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iteration for Volume =          20 and LBP =          20

0  WEIGHT     WEIGHT    LCG OF WEIGHT      -- SECTION MODULUS --
```

STATION (FROM FP)	(TONS)	FROM AMIDSHIPS (FT,+FWD)	(INCH**2-FEET) DECK	KEEL
-29.00				
0.	28.68	218.15		
20.40	42.43	193.80		
40.80	80.51	173.40		
61.20	106.63	153.00		
81.60	204.55	132.60		
102.00	233.93	112.20		
122.40	282.89	91.80		
142.80	290.51	71.40		
163.20	196.93	51.00		
183.60	191.49	30.60		
204.00	241.54	10.20		
224.40	255.69	-10.20		
244.80	245.90	-30.60		
265.20	233.93	-51.00		
285.60	302.47	-71.40		
306.00	255.69	-91.80		
326.40	179.53	-112.20		
346.80	181.70	-132.60		
367.20	124.04	-153.00		
387.60	159.94	-173.40		
408.00	132.74	-193.80		
420.00	16.00	-210.00		

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 13 DATE- 9-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING

0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	28.054	0.	195.718	10.102	291.826
-23.914	28.225	0.	200.200	9.976	289.052
-19.432	28.415	0.	204.682	9.871	286.824
-14.949	28.506	0.080	209.165	9.884	284.684
-10.467	28.549	8.762	213.647	9.896	283.339
-5.985	28.592	21.573	218.129	9.908	282.791
-1.503	28.635	38.512	222.612	9.921	283.040
2.980	28.537	67.624	227.094	10.015	284.084
7.462	28.367	100.879	231.576	10.162	285.926
11.944	28.198	133.407	236.058	10.310	288.564
16.427	28.029	165.210	240.541	10.458	291.998
20.909	27.836	196.286	245.023	10.612	296.290
25.391	27.462	226.637	249.505	10.885	302.085
29.873	27.089	256.261	253.988	11.159	307.776
34.356	26.715	285.159	258.470	11.432	313.363
38.838	26.342	313.330	262.952	11.705	318.845
43.320	25.885	338.037	267.434	12.0[illegible]2	324.223
47.803	25.362	358.630	271.917	12.414	329.496
52.285	24.840	376.889	276.399	12.795	334.665
56.767	24.317	392.814	280.881	13.176	339.729
61.249	23.794	406.406	285.364	13.557	344.690
65.732	23.192	417.664	289.846	14.015	349.792
70.214	22.590	426.588	294.328	14.477	354.751
74.696	21.988	433.178	298.810	14.938	359.553
79.179	21.386	437.435	303.293	15.400	364.196
83.661	20.778	438.957	307.775	15.878	368.682
88.143	20.162	438.653	312.257	16.380	373.009
92.625	19.547	437.354	316.740	16.882	377.179
97.108	18.931	435.059	321.222	17.384	381.190
101.590	18.316	431.769	325.704	17.886	385.044
106.072	17.737	427.484	330.186	18.377	388.538
110.555	17.162	422.204	334.669	18.866	391.260

115.037	16.587	415.929	339.151	19.354	393.200
119.519	16.012	408.659	343.633	19.843	394.357
124.001	15.465	400.517	348.116	20.308	394.730
128.484	14.970	392.335	352.598	20.717	394.321
132.966	14.476	384.237	357.080	21.126	393.128
137.448	13.981	376.222	361.562	21.535	391.153
141.931	13.486	368.291	366.045	21.944	388.395
146.413	13.079	360.444	370.527	22.243	384.615
150.895	12.692	352.680	375.009	22.503	378.259
155.377	12.305	345.000	379.491	22.763	369.153
159.860	11.919	337.404	383.974	23.023	357.301
164.342	11.564	329.803	388.456	23.244	342.699
168.824	11.303	322.389	392.938	23.300	325.350
173.306	11.042	315.638	397.421	23.356	305.252
177.789	10.781	309.550	401.903	23.412	282.406
182.271	10.519	304.125	406.385	23.469	256.813
186.753	10.353	299.362	410.867	23.431	161.672
191.236	10.228	295.263	415.350	23.320	0.
195.718	10.102	291.826	419.831	23.165	0.

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 13 DATE- 9-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - SAGGING
0WAVE HEIGHT, 16.40 FT CENTER 0. FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000
DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION WEIGHT BUOYANCY SHEAR BENDING MOM WEIGHT BUOYANCY SHEAR MOMENT
STRESS (TONS/IN**2)
FT FM FP TONS TONS TONS FOOT-TONS ORD ORD ORD ORD
DECK KEEL

LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-29.00			0.	0.			0.	0.
	28.68	8.02			0.30	0.08		
0.			20.66	369.9			0.155	0.045
	42.43	70.06			0.64	1.05		
20.40			-6.97	655.8			-0.052	0.081
	80.51	151.76			1.21	2.28		
40.80			-78.22	-81.7			-0.588	-0.010
	106.63	215.59			1.60	3.24		
61.20			-187.18	-2708.6			-1.408	-0.333
	204.55	248.61			3.08	3.74		
81.60			-231.24	-6944.2			-1.740	-0.854
	233.93	254.60			3.52	3.83		
102.00			-251.91	-11879.6			-1.895	-1.460
	282.89	244.31			4.26	3.68		
122.40			-213.33	-16652.7			-1.605	-2.047
	290.51	224.38			4.37	3.38		
142.80			-147.20	-20366.5			-1.107	-2.504
	196.93	203.50			2.96	3.06		
163.20			-153.76	-23470.8			-1.157	-2.885
	191.49	184.23			2.88	2.77		
183.60			-146.50	-26562.4			-1.102	-3.265
	241.54	171.24			3.63	2.58		
204.00			-76.20	-28849.2			-0.573	-3.546
	255.69	165.48			3.85	2.49		
224.40			14.01	-29487.3			0.105	-3.625
	245.90	168.04			3.70	2.53		
244.80			91.87	-28394.8			0.691	-3.490
	233.93	180.08			3.52	2.71		
265.20			145.72	-25946.0			1.096	-3.189
	302.47	194.34			4.55	2.92		
285.60			253.85	-21847.2			1.910	-2.686
	255.69	207.62			3.85	3.12		
306.00			301.92	-16156.6			2.271	-1.986
	179.53	219.47			2.70	3.30		
326.40			261.98	-10386.3			1.971	-1.277
	181.70	228.20			2.73	3.43		

346.80			215.48	-5507.3			1.621	-0.677
	124.04	228.76			1.87	3.44		
367.20			110.76	-2186.6			0.833	-0.269
	159.94	216.46			2.41	3.26		
387.60			54.24	-545.1			0.408	-0.067
	132.74	175.47			2.00	2.64		
408.00			11.51	27.8			0.087	0.003
	16.00	27.51			0.41	0.70		
420.00			0.	1.0			0.	0.000

MOMENT AT ZERO SHEAR= -29509.4 FOOT-TONS LOCATED 221.248 FT FROM FP
1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 13 DATE- 9-Aug-90
0 LONGITUDINAL STRENGTH CALCULATIONS - HOGGING
0DRAFTS AND SECTIONAL AREAS AT VARIOUS INPUT STATIONS

LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-27.947	2.480	0.	195.718	21.717	816.530
-23.914	2.410	0.	200.200	21.906	827.601
-19.432	2.332	0.	204.682	22.062	835.551
-14.949	2.317	0.	209.165	22.026	838.249
-10.467	2.333	0.	213.647	21.990	838.026
-5.985	2.349	0.	218.129	21.954	834.882
-1.503	2.365	0.	222.612	21.918	828.817
2.980	2.467	0.	227.094	21.759	819.832
7.462	2.613	0.	231.576	21.519	807.927
11.944	2.759	0.972	236.058	21.279	793.100
16.427	2.905	2.938	240.541	21.040	775.352
20.909	3.067	5.373	245.023	20.792	754.710
25.391	3.348	8.275	249.505	20.403	732.269
29.873	3.629	11.645	253.988	20.014	708.085
34.356	3.910	15.484	258.470	19.625	682.156
38.838	4.192	19.790	262.952	19.237	654.485
43.320	4.544	24.912	267.434	18.808	625.070
47.803	4.950	31.440	271.917	18.339	593.912
52.285	5.357	39.292	276.399	17.871	561.010
56.767	5.764	48.468	280.881	17.403	526.365
61.249	6.172	58.968	285.364	16.934	489.976
65.732	6.687	70.791	289.846	16.453	453.231
70.214	7.202	83.938	294.328	15.971	417.288
74.696	7.717	98.409	298.810	15.489	382.135
79.179	8.231	114.204	303.293	15.007	347.773
83.661	8.783	131.446	307.775	14.541	314.202
88.143	9.378	150.404	312.257	14.099	281.422
92.625	9.974	171.024	316.740	13.658	249.432
97.108	10.569	193.306	321.222	13.216	218.233
101.590	11.164	217.250	325.704	12.774	187.825
106.072	11.796	242.857	330.186	12.401	158.737
110.555	12.432	270.125	334.669	12.040	131.862
115.037	13.067	299.056	339.151	11.679	107.218
119.519	13.703	329.649	343.633	11.317	84.803
124.001	14.334	362.340	348.116	10.988	64.617
128.484	14.956	396.285	352.598	10.735	46.660
132.966	15.578	430.129	357.080	10.482	30.933
137.448	16.200	463.872	361.562	10.228	17.435
141.931	16.823	497.516	366.045	9.975	6.167
146.413	17.381	531.059	370.527	9.815	0.
150.895	17.923	564.502	375.009	9.688	0.
155.377	18.466	597.845	379.491	9.560	0.
159.860	19.008	631.088	383.974	9.432	0.
164.342	19.513	663.836	388.456	9.331	0.
168.824	19.907	693.706	392.938	9.338	0.
173.306	20.300	720.890	397.421	9.346	0.

177.789	20.694	745.389	401.903	9.354	0.
182.271	21.088	767.202	406.385	9.361	0.
186.753	21.338	786.330	410.867	9.426	0.
191.236	21.527	802.773	415.350	9.536	0.
195.718	21.717	816.530	419.831	9.673	0.

1SHIP- FFG61 FULL LOAD COND. (COND. D) SERIAL NUMBER- 13 DATE- 9-Aug-90

0 LONGITUDINAL STRENGTH CALCULATIONS - HOGGING

0WAVE HEIGHT, 16.40 FT CENTER 0. FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000

DISPLACEMENT 3987.72 TONS SW LCG -6.009 FT FROM AMIDSHIPS (+ FWD)

0LOCATION	WEIGHT	BUOYANCY	SHEAR	BENDING MOM	WEIGHT	BUOYANCY	SHEAR	MOMENT
STRESS (TONS/IN**2)								
FT FM FP	TONS	TONS	TONS	FOOT-TONS	ORD	ORD	ORD	ORD
DECK	KEEL							
-29.00			0.	0.			0.	0.
	28.68	0.			0.30	0.		
0.			28.68	405.8			0.216	0.050
	42.43	0.73			0.64	0.01		
20.40			70.38	1421.1			0.529	0.175
	80.51	7.37			1.21	0.11		
40.80			143.52	3619.4			1.080	0.445
	106.63	22.18			1.60	0.33		
61.20			227.97	7445.3			1.715	0.915
	204.55	51.75			3.08	0.78		
81.60			380.78	13718.4			2.865	1.686
	233.93	98.23			3.52	1.48		
102.00			516.47	22965.7			3.885	2.823
	282.89	164.36			4.26	2.47		
122.40			635.00	34840.2			4.777	4.283
	290.51	249.05			4.37	3.75		
142.80			676.47	48369.7			5.089	5.946
	196.93	338.11			2.96	5.09		
163.20			535.29	60880.1			4.027	7.484
	191.49	419.14			2.88	6.31		
183.60			307.64	69594.3			2.314	8.555
	241.54	471.33			3.63	7.09		
204.00			77.85	73587.6			0.586	9.046
	255.69	486.85			3.85	7.33		
224.40			-153.30	72808.7			-1.153	8.950
	245.90	463.79			3.70	6.98		
244.80			-371.20	67389.8			-2.793	8.284
	233.93	408.51			3.52	6.15		
265.20			-545.78	57921.8			-4.106	7.120
	302.47	330.47			4.55	4.97		
285.60			-573.78	46351.9			-4.317	5.698
	255.69	236.84			3.85	3.56		
306.00			-554.93	34680.0			-4.175	4.263
	179.53	148.00			2.70	2.23		
326.40			-523.40	23538.1			-3.938	2.893
	181.70	71.63			2.73	1.08		
346.80			-413.33	13871.7			-3.110	1.705
	124.04	19.30			1.87	0.29		
367.20			-308.59	6441.9			-2.322	0.792
	159.94	0.09			2.41	0.00		
387.60			-148.74	1776.4			-1.119	0.218
	132.74	0.			2.00	0.		
408.00			-16.00	96.1			-0.120	0.012
	16.00	0.			0.41	0.		
420.00			0.	0.			0.	0.

MOMENT AT ZERO SHEAR= 73854.1 FOOT-TONS LOCATED 210.836 FT FROM FP

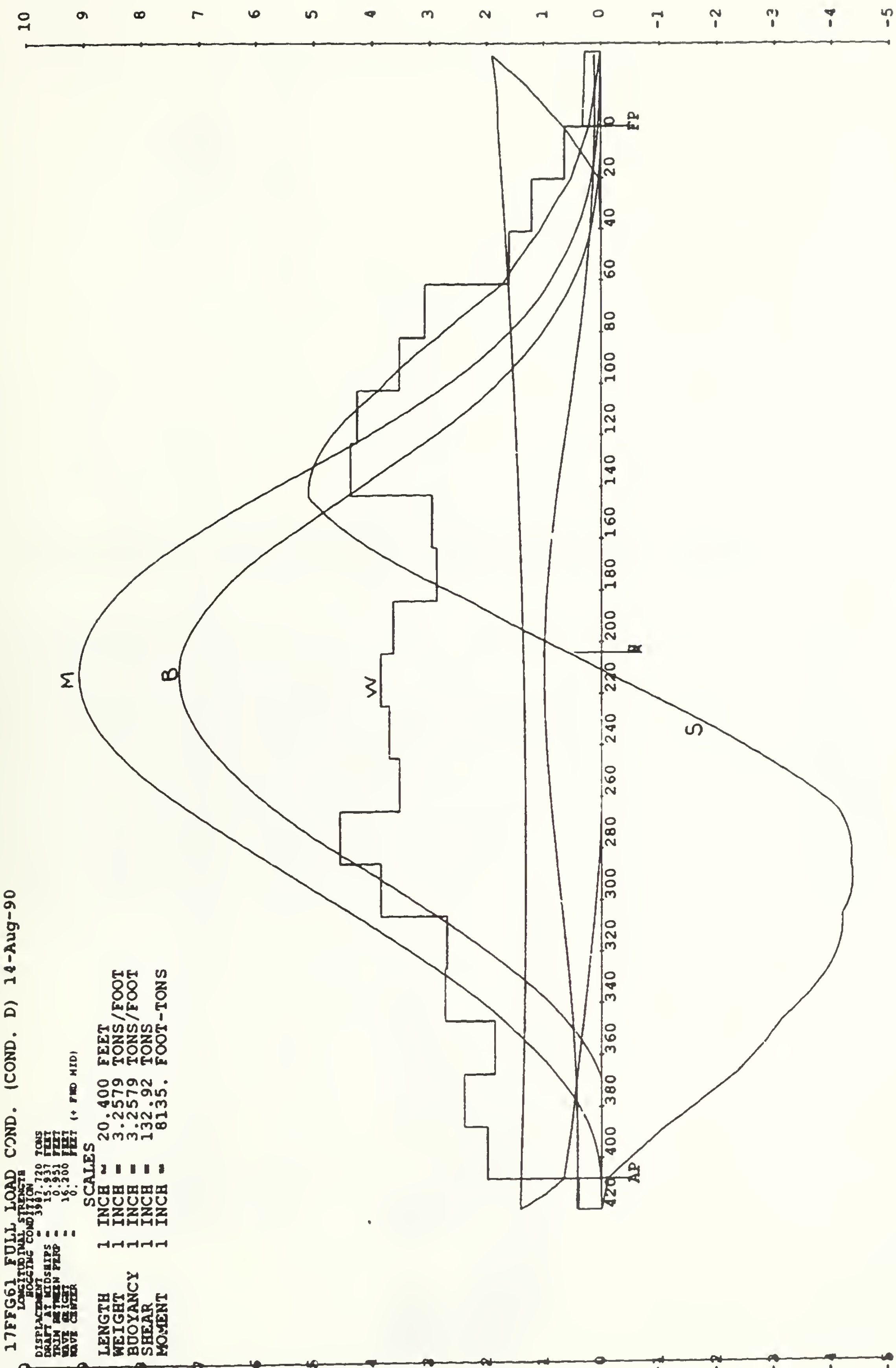

Figure B-9: SHCP Results, Full Load, Seastate 6, Hogging

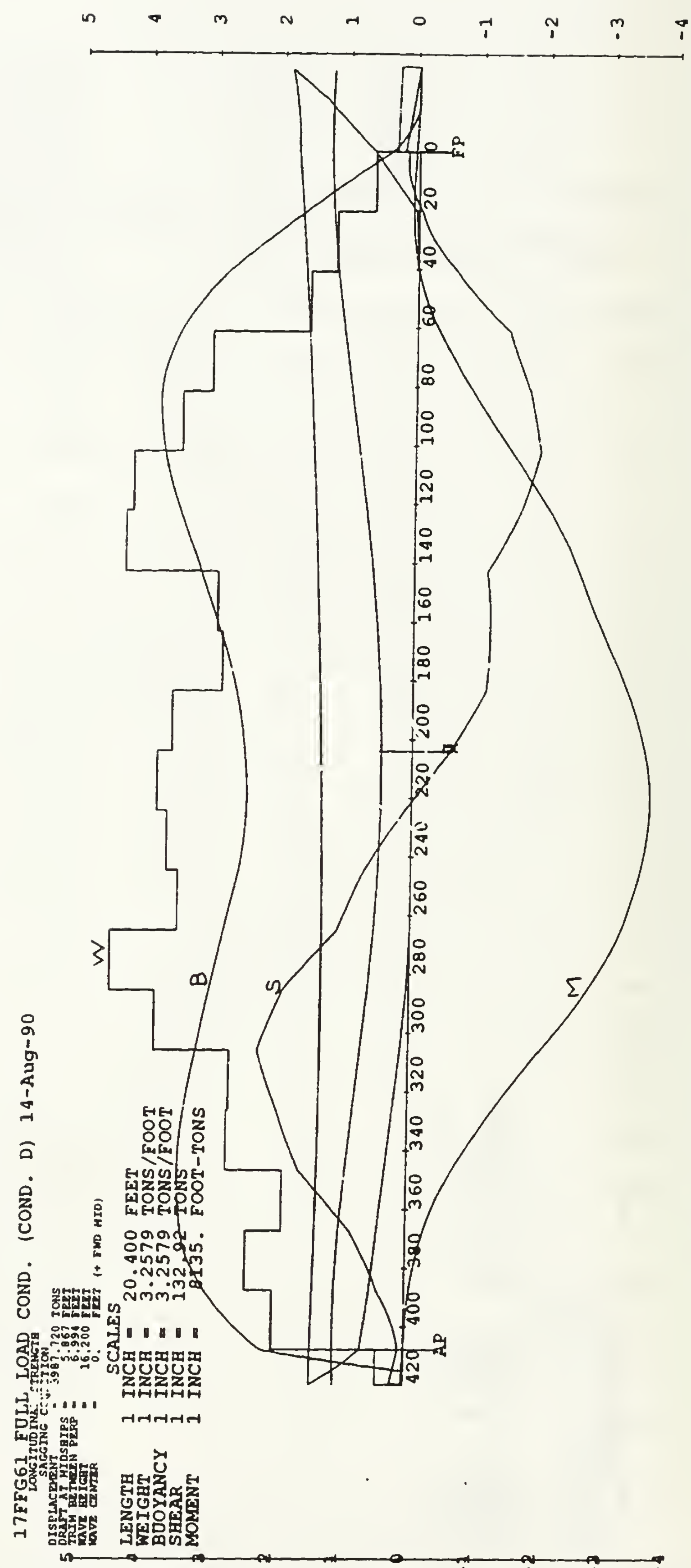

Figure B-10: SHCP Results, Full Load, Seastate 6, Sagging

Appendix C: Hull Flexure, Displacement and Rotation

FULL LOAD, SEASTATE 0

CONDITION:	FULL LOAD
SEASTATE:	0
HOG/SAG:	N/A

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP ft	MOMENT ft-ltons	I in^2ft^	M/E/I ft^-1	1st Int -	2nd Int ft	2nd Int inches	Corr inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.5563
1	20.4	-1317.6	106400	-9.241E-07	-1.66E-05	-0.0002733	-0.0033	0.9455
2	40.8	-2761.1	108500	-1.899E-06	-4.54E-05	-0.0009056	-0.0109	1.3298
3	61.2	-4455.2	110681	-3.004E-06	-9.54E-05	-0.0023418	-0.0281	1.7044
4	81.6	-6729.2	112994	-4.444E-06	-0.000171	-0.005063	-0.0608	2.0635
5	102.0	-10047.6	102384	-7.324E-06	-0.000291	-0.0097834	-0.1174	2.3987
6	122.4	-14477.6	136770	-7.900E-06	-0.000447	-0.017312	-0.2077	2.7002
7	142.8	-19920.2	130123	-1.142E-05	-0.000644	-0.0284349	-0.3412	2.9585
8	163.2	-24886.1	133311	-1.393E-05	-0.000902	-0.0442062	-0.5305	3.1611
9	183.6	-27840.7	154307	-1.346E-05	-0.001182	-0.0654657	-0.7856	3.2978
10	204.0	-28854.4	165435	-1.302E-05	-0.001452	-0.0923306	-1.1080	3.3672
11	224.4	-28373.6	162374	-1.304E-05	-0.001718	-0.1246614	-1.4959	3.3711
12	244.8	-26453	152744	-1.292E-05	-0.001983	-0.1624044	-1.9489	3.3100
13	265.2	-23057.2	135444	-1.270E-05	-0.002244	-0.2055153	-2.4662	3.1845
14	285.6	-19135.5	110066	-1.297E-05	-0.002506	-0.253964	-3.0476	2.9949
15	306.0	-15524.7	89467	-1.295E-05	-0.00277	-0.3077815	-3.6934	2.7409
16	326.4	-11750.3	69084	-1.269E-05	-0.003032	-0.3669639	-4.4036	2.4225
17	346.8	-7904.4	57188	-1.031E-05	-0.003267	-0.4312079	-5.1745	2.0434
18	367.2	-4261.3	39200	-8.112E-06	-0.003455	-0.4997628	-5.9972	1.6126
19	387.6	-1369.8	27700	-3.690E-06	-0.003575	-0.5714629	-6.8576	1.1440
20	408.0	-96.1	16200	-4.427E-07	-0.003617	-0.6448209	-7.7379	0.6555
20.59	420.0	-0.6	0	0.000E+00	-0.003622	-0.718655	-8.6239	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	-0.000725	x^0	dY/dX=		
	0.000025	x^1		0.000025	
	5.47E-07	x^2		1.09E-06	x^1
	-1.69E-08	x^3		-5.08E-08	x^2
	1.49E-11	x^4		5.95E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000127	-0.44	0			
CAS	120	-0.000473	-1.63	1.19	0.00		
STIR	208	-0.001411	-4.85	4.42	3.23	0.00	
MK 75 GUN	240	-0.001818	-6.25	5.81	4.62	1.40	0.00

80% FUEL CONDITION, SEASTATE 0

CONDITION:	80% FUEL LOAD
SEASTATE:	0
HOG/SAG:	N/A

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP		MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft		ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	*	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	*	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.5852
1	20.4	*	-1323.3	106400	-9.281E-07	-1.66E-05	-0.0002737	-0.0033	0.9948
2	40.8	*	-2801.8	108500	-1.927E-06	-4.58E-05	-0.0009102	-0.0109	1.3993
3	61.2	*	-4586.3	110681	-3.092E-06	-9.70E-05	-0.002366	-0.0284	1.7940
4	81.6	*	-7029.2	112994	-4.642E-06	-0.000176	-0.0051487	-0.0618	2.1728
5	102.0	*	-10615.5	102384	-7.738E-06	-0.000302	-0.0100241	-0.1203	2.5265
6	122.4	*	-15202	136770	-8.295E-06	-0.000466	-0.0178556	-0.2143	2.8447
7	142.8	*	-20702.9	130123	-1.187E-05	-0.000671	-0.0294533	-0.3534	3.1177
8	163.2	*	-25787.7	133311	-1.444E-05	-0.00094	-0.0458866	-0.5506	3.3326
9	183.6	*	-28957.4	154307	-1.400E-05	-0.00123	-0.068016	-0.8162	3.4793
10	204.0	*	-30373.3	165435	-1.370E-05	-0.001512	-0.0959868	-1.1518	3.5558
11	224.4	*	-30274.4	162374	-1.391E-05	-0.001794	-0.1297133	-1.5566	3.5632
12	244.8	*	-28725.1	152744	-1.403E-05	-0.002079	-0.1692206	-2.0306	3.5013
13	265.2	*	-25162.7	135444	-1.386E-05	-0.002364	-0.2145382	-2.5745	3.3697
14	285.6	*	-20544.8	110066	-1.393E-05	-0.002647	-0.26565	-3.1878	3.1685
15	306.0	*	-16434.6	89467	-1.371E-05	-0.002929	-0.3225291	-3.8703	2.8981
16	326.4	*	-12306.2	69084	-1.329E-05	-0.003205	-0.3850929	-4.6211	2.5595
17	346.8	*	-8202.7	57188	-1.070E-05	-0.003449	-0.4529627	-5.4356	2.1573
18	367.2	*	-4388.6	39200	-8.355E-06	-0.003644	-0.5253121	-6.3037	1.7012
19	387.6	*	-1401.3	27700	-3.775E-06	-0.003767	-0.6009064	-7.2109	1.2063
20	408.0	*	-96	16200	-4.422E-07	-0.00381	-0.6782015	-8.1384	0.6909
20.59	420.0	*	-0.4	0	0.000E+00	-0.003815	-0.7559814	-9.0718	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP, ft; y=2nd Iter., ft)

Y=	-0.000861	x^0	dY/dX=		
	0.0000219	x^1		0.0000219	
	7.18E-07	x^2		1.44E-06	x^1
	-1.88E-08	x^3		-5.63E-08	x^2
	1.64E-11	x^4		6.58E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000131	-0.45	0			
CAS	120	-0.000503	-1.73	1.28	0.00		
STIR	208	-0.001522	-5.23	4.78	3.51	0.00	
MK 75 GUN	240	-0.001966	-6.76	6.31	5.03	1.52	0.00

60% FUEL CONDITION, SEASTATE 0

CONDITION:	60% FUEL LOAD
SEASTATE:	0
HOG/SAG:	N/A

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP		MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int
	ft		ft-ltons	in^2ft^	ft^-1	-	ft	inches
-1.42	-29.0	*	0	0	0.000E+00	0	0	0.0000
0	0.0	*	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007
1	20.4	*	-1322.8	106400	-9.278E-07	-1.66E-05	-0.0002737	-0.0033
2	40.8	*	-2798.8	108500	-1.925E-06	-4.57E-05	-0.0009098	-0.0109
3	61.2	*	-5036.6	110681	-3.396E-06	-0.0001	-0.0023964	-0.0288
4	81.6	*	-8388.8	112994	-5.540E-06	-0.000191	-0.0053663	-0.0644
5	102.0	*	-12882.2	102384	-9.390E-06	-0.000343	-0.0108192	-0.1298
6	122.4	*	-17935.6	136770	-9.786E-06	-0.000539	-0.0198206	-0.2378
7	142.8	*	-23283.3	130123	-1.335E-05	-0.000775	-0.0332245	-0.3987
8	163.2	*	-28038.4	133311	-1.570E-05	-0.001071	-0.052058	-0.6247
9	183.6	*	-30888.1	154307	-1.494E-05	-0.001384	-0.077101	-0.9252
10	204.0	*	-31997.5	165435	-1.443E-05	-0.001683	-0.1083871	-1.3006
11	224.4	*	-31609.7	162374	-1.453E-05	-0.001979	-0.1457422	-1.7489
12	244.8	*	-29792.6	152744	-1.456E-05	-0.002275	-0.1891363	-2.2696
13	265.2	*	-25987.2	135444	-1.432E-05	-0.00257	-0.2385604	-2.8627
14	285.6	*	-21154	110066	-1.434E-05	-0.002862	-0.2939705	-3.5276
15	306.0	*	-16859	89467	-1.406E-05	-0.003152	-0.3553178	-4.2638
16	326.4	*	-12577.9	69084	-1.359E-05	-0.003434	-0.4224971	-5.0700
17	346.8	*	-8355.8	57188	-1.090E-05	-0.003684	-0.495101	-5.9412
18	367.2	*	-4456.7	39200	-8.484E-06	-0.003882	-0.5722702	-6.8672
19	387.6	*	-1418.7	27700	-3.822E-06	-0.004007	-0.6527368	-7.8328
20	408.0	*	-95.9	16200	-4.418E-07	-0.004051	-0.7349275	-8.8191
20.59	420.0	*	-0.3	0	0.000E+00	-0.004055	-0.8176077	-9.8113

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP, ft; y=2nd Iter., ft)

Y=	-0.000642	x^0	dY/dX=		
	0.000044	x^1		0.000044	
	4.50E-07	x^2		9.00E-07	x^1
	-1.98E-08	x^3		-5.94E-08	x^2
	1.82E-11	x^4		7.28E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR
MK 13 GML	70	-0.000159	-0.55	0		
CAS	120	-0.000578	-1.99	1.44	0.00	
STIR	208	-0.001684	-5.79	5.24	3.80	0.00
MK 75 GUN	240	-0.002155	-7.41	6.86	5.42	1.62

MINIMUM OPERATING CONDITION, SEASTATE 0

CONDITION:	MINIMUM OPERATING LOAD
SEASTATE:	0
HOG/SAG:	N/A

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.6350
1	20.4	-1325.6	106400	-9.297E-07	-1.67E-05	-0.0002739	-0.0033	1.0797
2	40.8	-2819.1	108500	-1.939E-06	-4.59E-05	-0.0009121	-0.0109	1.5193
3	61.2	-5002.5	110681	-3.373E-06	-0.0001	-0.0024014	-0.0288	1.9487
4	81.6	-8240.4	112994	-5.442E-06	-0.00019	-0.0053606	-0.0643	2.3604
5	102.0	-12670.8	102384	-9.236E-06	-0.00034	-0.010764	-0.1292	2.7428
6	122.4	-18527.2	136770	-1.011E-05	-0.000537	-0.0197071	-0.2365	3.0827
7	142.8	-24971.6	130123	-1.432E-05	-0.000786	-0.0332046	-0.3985	3.3680
8	163.2	-29803.1	133311	-1.668E-05	-0.001102	-0.0524697	-0.6296	3.5840
9	183.6	-32091.9	154307	-1.552E-05	-0.001431	-0.078311	-0.9397	3.7212
10	204.0	-32334.4	165435	-1.459E-05	-0.001738	-0.1106351	-1.3276	3.7805
11	224.4	-30967.1	162374	-1.423E-05	-0.002032	-0.1490897	-1.7891	3.7663
12	244.8	-28149.7	152744	-1.375E-05	-0.002317	-0.1934543	-2.3215	3.6812
13	265.2	-24168.6	135444	-1.332E-05	-0.002594	-0.2435467	-2.9226	3.5273
14	285.6	-19967.3	110066	-1.354E-05	-0.002867	-0.2992495	-3.5910	3.3061
15	306.0	-16165.7	89467	-1.348E-05	-0.003143	-0.3605576	-4.3267	3.0176
16	326.4	-12200.9	69084	-1.318E-05	-0.003415	-0.4274513	-5.1294	2.6622
17	346.8	-8277.5	57188	-1.080E-05	-0.00366	-0.4996141	-5.9954	2.2434
18	367.2	-4534.3	39200	-8.632E-06	-0.003858	-0.5762939	-6.9155	1.7705
19	387.6	-1438.4	27700	-3.875E-06	-0.003985	-0.6562968	-7.8756	1.2577
20	408.0	-96.8	16200	-4.459E-07	-0.00403	-0.7380505	-8.8566	0.7239
20.59	420.0	-0.9	0	0.000E+00	-0.004034	-0.8203003	-9.8436	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	-0.00059	x^0	dY/dX=		
	0.0000565	x^1		0.0000565	
	3.47E-07	x^2		6.94E-07	x^1
	-2.01E-08	x^3		-6.03E-08	x^2
	1.92E-11	x^4		7.70E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000164	-0.56	0			
CAS	120	-0.000595	-2.05	1.48	0.00		
STIR	208	-0.001715	-5.89	5.33	3.85	0.00	
MK 75 GUN	240	-0.002185	-7.51	6.95	5.47	1.62	0.00

FULL LOAD, SEASTATE 2, HOGGING

CONDITION: FULL LOAD
SEASTATE: 2
HOG/SAG: HOGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.6134
1	20.4	-1330.3	106400	-9.330E-07	-1.67E-05	-0.0002742	-0.0033	1.0428
2	40.8	-2850.9	108500	-1.961E-06	-4.62E-05	-0.0009157	-0.0110	1.4671
3	61.2	-4732.8	110681	-3.191E-06	-9.88E-05	-0.0023944	-0.0287	1.8814
4	81.6	-7327	112994	-4.839E-06	-0.000181	-0.0052445	-0.0629	2.2792
5	102.0	-11089.3	102384	-8.083E-06	-0.000312	-0.0102744	-0.1233	2.6508
6	122.4	-16048.9	136770	-8.757E-06	-0.000484	-0.0184008	-0.2208	2.9853
7	142.8	-22045.7	130123	-1.264E-05	-0.000703	-0.0305057	-0.3661	3.2720
8	163.2	-27518.1	133311	-1.540E-05	-0.000989	-0.0477552	-0.5731	3.4970
9	183.6	-30861.9	154307	-1.493E-05	-0.001298	-0.0710783	-0.8529	3.6491
10	204.0	-32092.8	165435	-1.448E-05	-0.001598	-0.1006161	-1.2074	3.7267
11	224.4	-31627.1	162374	-1.454E-05	-0.001894	-0.1362313	-1.6348	3.7313
12	244.8	-29518.6	152744	-1.442E-05	-0.002189	-0.1778778	-2.1345	3.6635
13	265.2	-25759.9	135444	-1.419E-05	-0.002481	-0.2255141	-2.7062	3.5239
14	285.6	-21350.5	110066	-1.448E-05	-0.002773	-0.2791104	-3.3493	3.3127
15	306.0	-17191.3	89467	-1.434E-05	-0.003067	-0.3386874	-4.0642	3.0298
16	326.4	-12876.1	69084	-1.391E-05	-0.003356	-0.4042014	-4.8504	2.6756
17	346.8	-8557.4	57188	-1.117E-05	-0.003611	-0.4752633	-5.7032	2.2549
18	367.2	-4556.4	39200	-8.674E-06	-0.003814	-0.5509985	-6.6120	1.7780
19	387.6	-1446.9	27700	-3.898E-06	-0.003942	-0.6301059	-7.5613	1.2607
20	408.0	-98.9	16200	-4.556E-07	-0.003986	-0.7109743	-8.5317	0.7223
20.59	420.0	-3	0	0.000E+00	-0.003991	-0.7923431	-9.5081	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP, ft; y=2nd Iter., ft)

Y=	-0.000905	x^0	dY/dX=		
	0.0000262	x^1		0.0000262	
	7.62E-07	x^2		1.52E-06	x^1
	-1.99E-08	x^3		-5.96E-08	x^2
	1.77E-11	x^4		7.06E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000135	-0.46	0			
CAS	120	-0.000528	-1.81	1.35	0.00		
STIR	208	-0.001601	-5.51	5.04	3.69	0.00	
MK 75 GUN	240	-0.002067	-7.11	6.64	5.29	1.60	0.00

FULL LOAD, SEASTATE 2, SAGGING

CONDITION:	FULL LOAD
SEASTATE:	2
HOG/SAG:	SAGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.4980
1	20.4	-1302.9	106400	-9.138E-07	-1.65E-05	-0.0002722	-0.0033	0.8463
2	40.8	-2663.7	108500	-1.832E-06	-4.45E-05	-0.0008944	-0.0107	1.1896
3	61.2	-4161.9	110681	-2.806E-06	-9.18E-05	-0.0022847	-0.0274	1.5237
4	81.6	-6106.4	112994	-4.033E-06	-0.000162	-0.0048692	-0.0584	1.8435
5	102.0	-8972.6	102384	-6.540E-06	-0.000269	-0.0092653	-0.1112	2.1416
6	122.4	-12867.2	136770	-7.021E-06	-0.000408	-0.0161723	-0.1941	2.4095
7	142.8	-17752.9	130123	-1.018E-05	-0.000583	-0.0262798	-0.3154	2.6391
8	163.2	-22211.8	133311	-1.243E-05	-0.000814	-0.04053	-0.4864	2.8189
9	183.6	-24777.8	154307	-1.198E-05	-0.001063	-0.0596735	-0.7161	2.9400
10	204.0	-25574.9	165435	-1.154E-05	-0.001303	-0.0838044	-1.0057	3.0012
11	224.4	-25079	162374	-1.153E-05	-0.001538	-0.1127818	-1.3534	3.0043
12	244.8	-23345.5	152744	-1.141E-05	-0.001772	-0.1465445	-1.7585	2.9499
13	265.2	-20312.4	135444	-1.119E-05	-0.002002	-0.1850441	-2.2205	2.8388
14	285.6	-16880.2	110066	-1.145E-05	-0.002233	-0.22825	-2.7390	2.6711
15	306.0	-13821.9	89467	-1.153E-05	-0.002468	-0.2762012	-3.3144	2.4465
16	326.4	-10595.7	69084	-1.145E-05	-0.002702	-0.328933	-3.9472	2.1645
17	346.8	-7231.1	57188	-9.436E-06	-0.002915	-0.3862277	-4.6347	1.8278
18	367.2	-3955.8	39200	-7.531E-06	-0.003088	-0.4474602	-5.3695	1.4438
19	387.6	-1290.1	27700	-3.476E-06	-0.0032	-0.5116031	-6.1392	1.0249
20	408.0	-95.3	16200	-4.390E-07	-0.00324	-0.5772983	-6.9276	0.5874
20.59	420.0	-0.1	0	0.000E+00	-0.003245	-0.6434465	-7.7214	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	-0.000592	x^0	dY/dX=		
	0.0000249	x^1		0.0000249	
	3.69E-07	x^2		7.39E-07	x^1
	-1.50E-08	x^3		-4.49E-08	x^2
	1.29E-11	x^4		5.18E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN)			
				MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000126	-0.43	0			
CAS	120	-0.000444	-1.53	1.09	0.00		
STIR	208	-0.0013	-4.47	4.04	2.94	0.00	
MK 75 GUN	240	-0.001671	-5.75	5.31	4.22	1.28	0.00

FULL LOAD, SEASTATE 4, HOGGING

CONDITION:	FULL LOAD
SEASTATE:	4
HOG/SAG:	HOGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	0.8804
1	20.4	-1371.6	106400	-9.620E-07	-1.70E-05	-0.0002772	-0.0033	1.4976
2	40.8	-3181.4	108500	-2.188E-06	-4.91E-05	-0.0009515	-0.0114	2.1094
3	61.2	-5865.1	110681	-3.955E-06	-0.000112	-0.0025925	-0.0311	2.7095
4	81.6	-9921.3	112994	-6.553E-06	-0.000219	-0.0059658	-0.0716	3.2888
5	102.0	-15791.1	102384	-1.151E-05	-0.000403	-0.0123115	-0.1477	3.8325
6	122.4	-23335	136770	-1.273E-05	-0.00065	-0.0230586	-0.2767	4.3234
7	142.8	-32090.2	130123	-1.840E-05	-0.000968	-0.0395673	-0.4748	4.7451
8	163.2	-40116.2	133311	-2.246E-05	-0.001385	-0.0635667	-0.7628	5.0769
9	183.6	-45431.3	154307	-2.197E-05	-0.001838	-0.0964395	-1.1573	5.3023
10	204.0	-47751.8	165435	-2.[illegible]54E-05	-0.002282	-0.1384618	-1.6615	5.4179
11	224.4	-47334.7	162374	-2.175E-05	-0.002723	-0.1895155	-2.2742	5.4250
12	244.8	-44235.7	152744	-2.161E-05	-0.003166	-0.2495857	-2.9950	5.3240
13	265.2	-38608.3	135444	-2.127E-05	-0.003603	-0.3186295	-3.8236	5.1153
14	285.6	-31729.9	110066	-2.151E-05	-0.00404	-0.3965865	-4.7590	4.7997
15	306.0	-24847.8	89467	-2.073E-05	-0.00447	-0.4833896	-5.8007	4.3779
16	326.4	-17907.4	69084	-1.934E-05	-0.004879	-0.5787562	-6.9451	3.8533
17	346.8	-11359.5	57188	-1.482E-05	-0.005228	-0.6818465	-8.1822	3.2360
18	367.2	-5732.9	39200	-1.091E-05	-0.00549	-0.7911694	-9.4940	2.5440
19	387.6	-1705.3	27700	-4.594E-06	-0.005648	-0.9047835	-10.8574	1.8004
20	408.0	-96	16200	-4.422E-07	-0.0057	-1.020535	-12.2464	1.0313
20.59	420.0	0.1	0	0.000E+00	-0.005704	-1.1368565	-13.6423	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP, ft; y=2nd Iter., ft)

Y=	-0.00179	x^0	dY/dX=	
	0.0000236	x^1	0.0000236	
	1.88E-06	x^2	3.76E-06	x^1
	-3.22E-08	x^3	-9.67E-08	x^2
	2.99E-11	x^4	1.20E-10	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000146	-0.50	0			
CAS	120	-0.000711	-2.45	1.94	0.00		
STIR	208	-0.002302	-7.91	7.41	5.47	0.00	
MK 75 GUN	240	-0.002991	-10.28	9.78	7.84	2.37	0.00

FULL LOAD, SEASTATE 4, SAGGING

CONDITION:	FULL LOAD
SEASTATE:	4
HOG/SAG:	SAGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.3	104300	-2.900E-07	-4.20E-06	-6.097E-05	-0.0007	0.1795
1	20.4	-1191	106400	-8.353E-07	-1.57E-05	-0.0002638	-0.0032	0.3038
2	40.8	-2034.7	108500	-1.399E-06	-3.85E-05	-0.0008163	-0.0098	0.4239
3	61.2	-2389.2	110681	-1.611E-06	-6.92E-05	-0.0019144	-0.0230	0.5375
4	81.6	-2489.8	112994	-1.644E-06	-0.000102	-0.0036645	-0.0440	0.6432
5	102.0	-2902.4	102384	-2.116E-06	-0.000141	-0.0061444	-0.0737	0.7402
6	122.4	-3960.7	136770	-2.161E-06	-0.000184	-0.0094604	-0.1135	0.8272
7	142.8	-5948.1	130123	-3.411E-06	-0.000241	-0.0138012	-0.1656	0.9018
8	163.2	-7801.9	133311	-4.367E-06	-0.000321	-0.019531	-0.2344	0.9598
9	183.6	-8386.4	154307	-4.056E-06	-0.000406	-0.0269464	-0.3234	0.9976
10	204.0	-8083	165435	-3.646E-06	-0.000485	-0.0360396	-0.4325	1.0152
11	224.4	-7511	162374	-3.452E-06	-0.000557	-0.0466725	-0.5601	1.0144
12	244.8	-6732.7	152744	-3.289E-06	-0.000626	-0.0587454	-0.7049	0.9962
13	265.2	-5563.2	135444	-3.065E-06	-0.000691	-0.0721808	-0.8662	0.9618
14	285.6	-4667.9	110066	-3.165E-06	-0.000755	-0.0869255	-1.0431	0.9116
15	306.0	-4509.3	89467	-3.761E-06	-0.000825	-0.1030389	-1.2365	0.8450
16	326.4	-4201.4	69084	-4.538E-06	-0.00091	-0.1207365	-1.4488	0.7593
17	346.8	-3444.6	57188	-4.495E-06	-0.001002	-0.1402375	-1.6829	0.6521
18	367.2	-2196.9	39200	-4.182E-06	-0.001091	-0.1615811	-1.9390	0.5227
19	387.6	-807.2	27700	-2.175E-06	-0.001155	-0.1844889	-2.2139	0.3746
20	408.0	-90	16200	-4.146E-07	-0.001182	-0.2083274	-2.4999	0.2153
20.59	420.0	-2.3	0	0.000E+00	-0.001186	-0.2324785	-2.7897	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	0.0001318	x^0	dY/dX=		
	0.0000161	x^1		0.0000161	
	-5.32E-07	x^2		-1.06E-06	x^1
	-2.27E-09	x^3		-6.80E-09	x^2
	8.61E-13	x^4		3.44E-12	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-9.06E-05	-0.31	0			
CAS	120	-0.000204	-0.70	0.39	0.00		
STIR	208	-0.000469	-1.61	1.30	0.91	0.00	
MK 75 GUN	240	-0.000584	-2.01	1.69	1.31	0.40	0.00

FULL LOAD, SEASTATE 6, HOGGING

CONDITION: FULL LOAD
SEASTATE: 6
HOG/SAG: HOGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP	MOMENT	I	M/E/I	1st Int	2nd Int	2nd Int	Corr
	ft	ft-ltons	in^2ft^	ft^-1	-	ft	inches	inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-405.8	104300	-2.904E-07	-4.21E-06	-6.105E-05	-0.0007	1.2890
1	20.4	-1421.1	106400	-9.967E-07	-1.73E-05	-0.0002808	-0.0034	2.1937
2	40.8	-3619.4	108500	-2.489E-06	-5.29E-05	-0.0009972	-0.0120	3.0924
3	61.2	-7445.3	110681	-5.020E-06	-0.000129	-0.0028576	-0.0343	3.9773
4	81.6	-13718.4	112994	-9.060E-06	-0.000273	-0.0069642	-0.0836	4.8353
5	102.0	-22965.7	102384	-1.674E-05	-0.000536	-0.0152199	-0.1826	5.6435
6	122.4	-34840.2	136770	-1.901E-05	-0.000901	-0.0298793	-0.3586	6.3749
7	142.8	-48369.7	130123	-2.774E-05	-0.001378	-0.0531219	-0.6375	7.0033
8	163.2	-60880.1	133311	-3.408E-05	-0.002008	-0.0876604	-1.0519	7.4961
9	183.6	-69594.3	154307	-3.366E-05	-0.002699	-0.1356781	-1.6281	7.8271
10	204.0	-73587.6	165435	-3.319E-05	-0.003381	-0.1976987	-2.3724	7.9502
11	224.4	-72808.7	162374	-3.346E-05	-0.004061	-0.2736096	-3.2833	7.9865
12	244.8	-67389.8	152744	-3.292E-05	-0.004738	-0.3633626	-4.3604	7.8168
13	265.2	-57921.8	135444	-3.191E-05	-0.0054	-0.4667685	-5.6012	7.4832
14	285.6	-46351.9	110066	-3.143E-05	-0.006046	-0.5835101	-7.0021	6.9896
15	306.0	-34680	89467	-2.893E-05	-0.006661	-0.7131211	-8.5575	6.3415
16	326.4	-23538.1	69084	-2.543E-05	-0.007216	-0.8546665	-10.2560	5.5502
17	346.8	-13871.7	57[illegible]58	-1.810E-05	-0.00766	-1.0063955	-12.0767	4.6368
18	367.2	-6441.9	39200	-1.226E-05	-0.007969	-1.1658125	-13.9897	3.6311
19	387.6	-1776.4	27700	-4.786E-06	-0.008143	-1.3301625	-15.9620	2.5661
20	408.0	-96.1	16200	-4.427E-07	-0.008197	-1.4968304	-17.9620	1.4734
20.59	420.0	0	0	0.000E+00	-0.008201	-1.6640882	-19.9691	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	-0.003548	x^0	dY/dX=		
	9.72E-06	x^1		9.72E-06	
	4.09E-06	x^2		8.18E-06	x^1
	-5.47E-08	x^3		-1.64E-07	x^2
	5.45E-11	x^4		2.18E-10	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	-0.000147	-0.51	0			
CAS	120	-0.000996	-3.42	2.92	0.00		
STIR	208	-0.003429	-11.79	11.28	8.37	0.00	
MK 75 GUN	240	-0.004469	-15.36	14.86	11.94	3.57	0.00

FULL LOAD, SEASTATE 6, SAGGING

CONDITION: FULL LOAD
SEASTATE: 6
HOG/SAG: SAGGING

E:	13400	ltons/in^2
Station Spacing :	20.4	ft
Max Dist Fwd FP :	29.0	ft
Max Dist Aft FP :	420.0	ft

Sta	Dist Aft FP ft	MOMENT ft-ltons	I in^2ft^	M/E/I ft^-1	1st Int -	2nd Int ft	2nd Int inches	Corr inches
-1.42	-29.0	0	0	0.000E+00	0	0	0.0000	0.0000
0	0.0	-369.9	104300	-2.647E-07	-3.84E-06	-5.565E-05	-0.0007	-0.5367
1	20.4	-655.8	106400	-4.600E-07	-1.12E-05	-0.0002093	-0.0025	-0.9156
2	40.8	81.7	108500	5.619E-08	-1.53E-05	-0.0004804	-0.0058	-1.2959
3	61.2	2708.6	110681	1.826E-06	3.85E-06	-0.0005976	-0.0072	-1.6744
4	81.6	6944.2	112994	4.586E-06	0.0000693	0.00014815	0.0018	-2.0425
5	102.0	11879.6	102384	8.659E-06	0.0002044	0.00293913	0.0353	-2.3860
6	122.4	16652.7	136770	9.086E-06	0.0003854	0.00895437	0.1075	-2.6909
7	142.8	20366.5	130123	1.168E-05	0.0005972	0.0189764	0.2277	-2.9477
8	163.2	23470.8	133311	1.314E-05	0.0008503	0.03374119	0.4049	-3.1476
9	183.6	26562.4	154307	1.285E-05	0.0011154	0.05379166	0.6455	-3.2841
10	204.0	28849.2	165435	1.301E-05	0.0013792	0.0792361	0.9508	-3.3558
11	224.4	29487.3	162374	1.355E-05	0.0016501	0.11013495	1.3216	-3.3621
12	244.8	28394.8	152744	1.387E-05	0.0019299	0.14665105	1.7598	-3.3009
13	265.2	25946	135444	1.430E-05	0.0022172	0.18895116	2.2674	-3.1704
14	285.6	21847.2	110066	1.481E-05	0.0025141	0.23721039	2.8465	-2.9683
15	306.0	16156.6	89467	1.348E-05	0.0028027	0.2914413	3.4973	-2.6946
16	326.4	10386.3	69084	1.122E-05	0.0030546	0.35118486	4.2142	-2.3548
17	346.8	5507.3	57188	7.187E-06	0.0032423	0.41541282	4.9850	-1.9611
18	367.2	2186.6	39200	4.163E-06	0.0033581	0.48273656	5.7928	-1.5303
19	387.6	545.1	27700	1.469E-06	0.0034155	0.55182697	6.6219	-1.0782
20	408.0	-27.8	16200	-1.281E-07	0.0034292	0.62164274	7.4597	-0.6175
20.59	420.0	-1	0	0.000E+00	0.0034279	0.69158464	8.2990	0.0000

FORTH ORDER LEAST-SQUARES POLYNOMIAL CURVE FIT (x=Ft Aft FP,ft; y=2nd Iter.,ft)

Y=	0.0010591	x^0	dY/dX=		
	-2.90E-05	x^1		-2.90E-05	
	-1.62E-06	x^2		-3.24E-06	x^1
	2.24E-08	x^3		6.71E-08	x^2
	-2.19E-11	x^4		-8.74E-11	x^3

ITEM	X-LOCATION FT AFT FP	SLOPE	MINUTES ARC	DIFFERENCE MATRIX (ARC-MIN) MK 13	CAS	STIR	MK75
MK 13 GML	70	0.0000433	0.15	0			
CAS	120	0.0003979	1.37	-1.22	0.00		
STIR	208	0.0014144	4.86	-4.71	-3.49	0.00	
MK 75 GUN	240	0.001851	6.36	-6.21	-5.00	-1.50	0.00

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